GROWING ENERGY CROPS ON MINNESOTA'S WETLANDS:

The Land Use Perspective

by JEFFREY P. ANDERSON
and WILLIAM J. CRAIG

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PREFACE

The Center for Urban and Regional Affairs (CURA) is one of several University of Minnesota departments working on a comprehensive study of the feasibility of developing Minnesota's wetlands to produce energy crops (or biomass). The study is coordinated through the University's Bioenergy Coordinating Office (BECO) and funded by a grant from the Energy Division of the Minnesota State Department of Energy and Development.

CURA's role in the study has been to investigate the land use aspects of using wetlands for growing biomass. Over the last three years CURA has produced a series of reports from the land use perspective: An Inventory of Minnesota's Wetlands and Their Suitability for Producing Bioenergy Crops (November 1980), A Study of Wetland Suitability for Bioenergy Development in Aitkin County, Minnesota (November 1981), Land Use Constraints on Wetland Biomass Development: A Case Study in Aitkin County, Minnesota (October 1981), Minnesota's Marginal Cropland (January 1982), Potential Bioenergy Lands in the White Earth Indian Reservation (February 1982), and The Potential for Wetland Bioenergy in Todd and Wadena Counties, Minnesota (October 1982).

Because these reports are quite long and filled with an abundance of technical detail they are not suitable for the general reader and were not published. This report attempts to present a more general picture of the land use aspects of growing energy crops in Minnesota and to demonstrate a process by which lands suitable for growing energy crops can be identified. The full reports are available for reading (or photocopying) at CURA and BECO, at the University, and the Energy Division at the Minnesota state offices.

ACKNOWLEDGMENTS

The authors are indebted to the University's Bioenergy Coordinating Office (BECO) for initiating and coordinating this study. Particularly helpful were its director, Professor Douglas Pratt, and assistant director, Nancy Andrews. Coordinating the project from the state was Ronald D. Visness.

Substantive assistance came from a number of people. Many economic constraints on wetland biomass development were articulated by a graduate student in Agricultural and Applied Economics, Catherine R. Friend. Aiding her (and us) were her advisors Professors Vernon Eidman and Lee Martin. The results of their work are documented in Friend's master's degree paper, "Cattails as as Alternative Source of Energy for Minnesota," (September 1981). Finally, professor of soil science Rouse Farnham provided biomass productivity ratings for different types of wetlands.

Technical support came from a variety of people. Computer work was handled admirably by graduate students Glenn Radde and Darrell Napton. Napton also coauthored the original Todd-Wadena report. They received invaluable assistance from Robert Smekofski of the state's Land Management Information Center. Difficult typing was handled easily by Chris Mckee and her staff.

Much data was collected and used which was not already part of the state data base in the Minnesota Land Management Information System (MLMIS). We here acknowledge the people who helped us access and interpret that information. We were assisted with data for Aitkin County by Dennis Asmussen, Barb Coffin and Lee Pfaunnmuller, Ted Loffstrom, David Meinicky, and George Orning and Rick Gelbman (DNR Planning). We were assisted with data for Todd and Wadena counties by the zoning officials of those two counties.

Finally, the authors owe a debt of gratitude to CURA's editor, Judith Weir. She is responsible for this publication, having distilled half-a-dozen reports and hundreds of pages into this one volume. The reader will benefit from this reduction and the clarity which her editing has added.

INTRODUCTION

Energy crops could provide an answer to this country's energy problems. If an easily transportable fuel could be produced in great quantities at a competitive price, that fuel could reduce or eliminate our dependence on the vagaries of foreign petroleum supplies while improving our balance of payments. Energy crops or biomass (as they are usually called in scientific circles) are currently being considered as just such a fuel. The use of biomass would reduce the problem of degrading our atmosphere with the carbon-dioxide produced when burning fossil fuels. If the biomass itself could be grown on land not otherwise useful, these large benefits could be gained at little cost to society.

These are the reasons behind the Wetland Biomass Project at the University of Minnesota. The project is a comprehensive study to explore the feasibility of growing energy crops in Minnesota. It is funded by the State of Minnesota. Botanists are looking at various wetland plants, especially cattails, to determine which plants are most efficient at converting sunlight into biomass and the conditions under which these plants are best grown. Initial results appear promising, with cattails producing about twice as much biomass per acre as corn. Agricultural engineers are looking at ways to harvest these wetland crops. Biochemists are studying ways to convert the crops into a useful energy source. Economists are making certain that the choices made produce results that are economically viable.

The availability of land for growing the biomass is the subject of study for land use planners at the University's Center for Urban and Regional Affairs (CURA). How many acres of wetlands exist in Minnesota? After allowing for economic constraints and land use conflicts, how many acres actually could be considered available for production. How would different technologies affect the amount of land available for energy crops? How could changes in public policy affect this availability? The answers to these questions are critical in determining the viability of a wetland biomass industry in Minnesota. For example, if the harvesting technology to be used requires draining an area before moving in harvesting equipment, followed by flooding before winter, no development can take place unless wetlands are found in close proximity to rivers or lakes.

This report describes the results of three years of study on the lands available for energy crops in Minnesota. Chapter 1 presents the early part of the study in which soil types were examined across the entire state and an inventory prepared of the state's wetlands. Factors were considered that might make these wetlands unsuited for growing bioenergy crops and a list of such possible constraints prepared. Constraints include both land use conflicts and economic limitations. Chapters 2 and 3 present two pilot studies--one in Aitkin County and the other in Todd and Wadena counties. Here a detailed analysis was prepared of the wetlands available for growing energy crops and how each of the constraints would affect the lands available. Finally, in Chapter 4, projections are made for the entire state, based on these two pilot studies, and further research and public policy issues are discussed. In Appendix B, brief consideration is given to other Minnesota lands, not wetlands, that might be suitable for growing energy crops.

Some of the results are relatively solid, others are more speculative. Perhaps more important than the results is the process used. No one knows just how wetland biomass development might take place. Understanding and knowledge are gained through a circular and cumulative process involving all researchers and policy makers. A small breakthrough in one area of study allows another to move forward and so on until the first area takes another step forward.

1. MINNESOTA'S WETLAND BASE

The lands best suited for energy crop production are provided by the wetlands of Minnesota. These lands, including peat and poorly drained mineral soils, at one time accounted for nearly one-third of Minnesota's total acreage. Today, many of these original wetlands are drained and used for agricultural purposes. Still remaining in the north, however, are large areas of wetlands that hold considerable potential for producing bioenergy crops.

An inventory of the state's wetlands is a natural starting point in assessing the land use prospects for energy crops in Minnesota. No such inventory existed. The closest thing to an estimate was a figure of 7.5 million acres of peatland used by the Minnesota Peat Project in the Department of Natural Resources. Satellite sensings available to the public through NASA's Landsat program are effective for locating open water, but not wet areas covered by vegetation. Therefore wet soils were used in preparing an inventory.

Peat, a major component of Minnesota's wetlands, is found in most regions of the state. The bulk of this resource developed on marshy landscapes of former glacial lake basins like that of Lake Agassiz which once covered the Red River Valley and much of north-central Minnesota. The remainder of Minnesota's peat deposits are scattered across the state in potholes and other depressions. These deposits are generally small in size and their entire acreage accounts for less than 15 percent of the state's total.

Wet mineral soils once covered much of Minnesota also. Most of these soils developed on level or depressional landscapes of glacial till and lake basins. Before the state was settled, these soils supported the wet prairie vegetation which stretched across the southern and western regions of Minnesota. Most of these fertile soils have been drained and now represent our most productive farmland. However, extensive deposits of these wet mineral soils can still be found in the north where their remoteness and cool climate preclude their use for agriculture.

To prepare an inventory we used the Minnesota Land Management Information System, a computerized geographic information system. MLMIS was developed under CURA and is now administered by the Land Management Information Center in the Minnesota State Planning Agency. The MLMIS computer files contain physical, cultural, and locational information for each forty acre parcel in the state. Data regarding these "forties" can be retrieved in a statistical, tabular, or map format. For some areas of the state, more than twenty categories of information exist for the forty acre parcels. Each category of information is labeled a variable (such as land use, ownership, or forest cover). Each variable contains a number of classes (such as spruce-fir, hardwoods, and pine for the variable "forest cover"). The computerized system allows several variables to be combined into a composite map or table. While forty acre analysis does not provide sufficient detail for site planning, it is appropriate for addressing land use questions on a regional scale.

To determine which lands in Minnesota would be suited for production of energy crops a series of constraints were applied to the total land base in Minnesota. First the soil type was considered, then the current land uses, the use of artificial drainage, the forest cover, and, finally, the ownership of the land. As each of these constraints was applied, by selecting relevant categories in the MLMIS system, the amount of suitable land was cut back, leaving an increasingly more accurate picture of how much land would be suited for energy crops and where that land is.

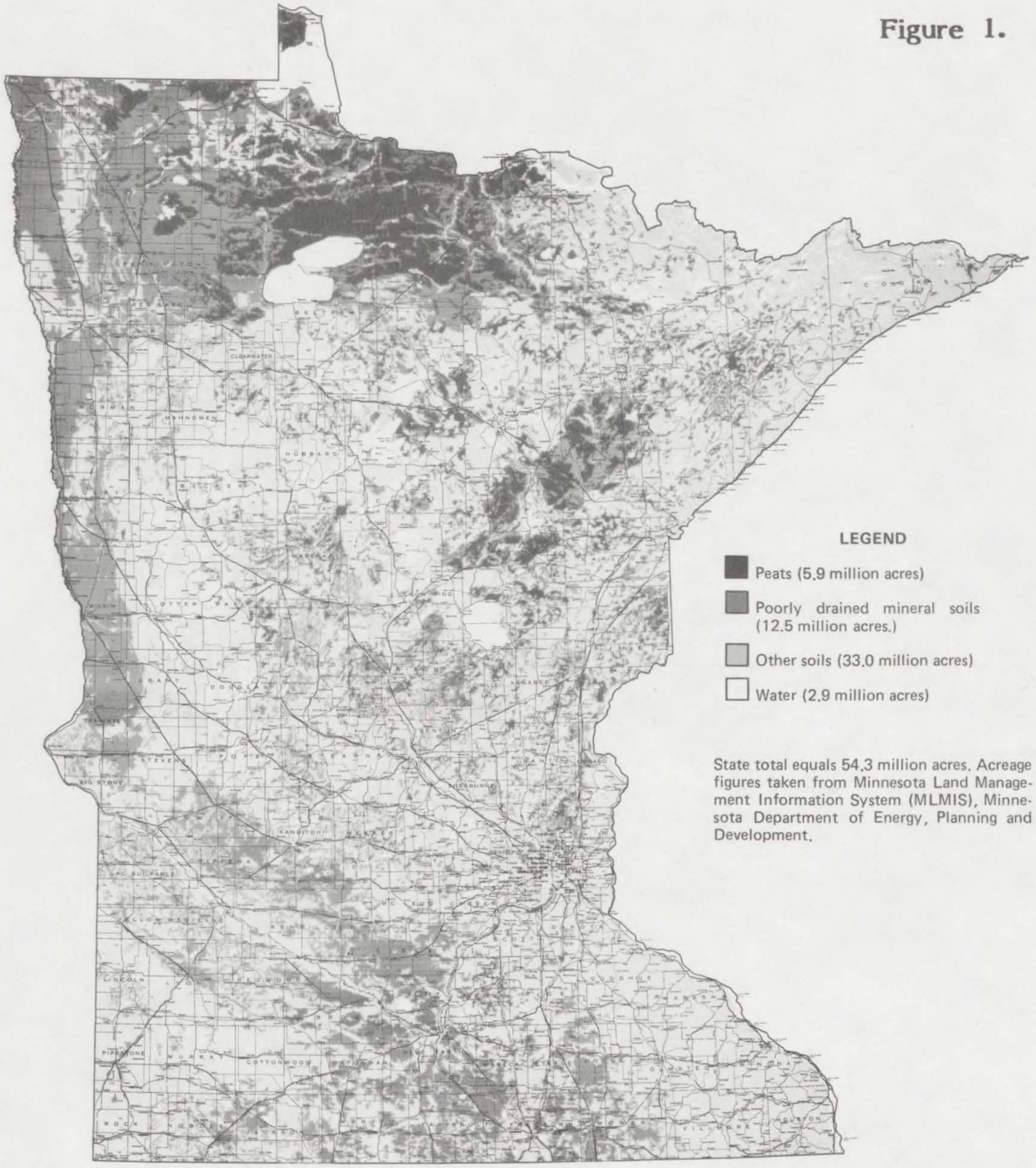
EXAMINING SOIL TYPES

The information on soil type in MLMIS derives from the Minnesota Soil Atlas.* These generalized maps provide the only complete set of soil maps for the state. There are nearly seventy separate classes of soil type, but for this study only two general categories were constructed: peat and wet mineral soil. The Atlas designates several types of peat soils but for this study they were combined into one "peat" category. Mineral soils are classified by a number of characteristics including whether or not they are well or poorly drained in their natural state. All poorly drained mineral soils were combined into one "wet mineral" category.

Peat and wet mineral soils were mapped and tallied (see Figure 1). A total of 18.4 million acres of naturally wet soils (peat and wet mineral) was identified, about one-third of the total land area of the state. These wet soils were found throughout the state. Of the total, 5.9 million acres of peat were identified, mostly in northern Minnesota. Note that this figure is considerably below the 7.5 million acre estimate which had been used by

*A product of the University of Minnesota Department of Soil Science in cooperation with the Soil Conservation Services, U.S. Department of Agriculture and the Minnesota Geological Survey.

Figure 1. NATURAL WETLANDS OF MINNESOTA



LEGEND

- Peats (5.9 million acres)
- Poorly drained mineral soils (12.5 million acres.)
- Other soils (33.0 million acres)
- Water (2.9 million acres)

State total equals 54.3 million acres. Acreage figures taken from Minnesota Land Management Information System (MLMIS), Minnesota Department of Energy, Planning and Development.

those investigating peat mining. Another 12.5 million acres of wet mineral soils exist largely in south-central and northwestern Minnesota.*

*See Appendix A for a county-by-county listing of these wetlands.

DETERMINING THE WETLAND BASE

Land Use

The areas designated in Figure 1 represent Minnesota's soils before settlement, in their natural state. To discover how much of this land is actually suitable for production of energy crops today we made use of the land use variables stored in the MLMIS system. The nine classes under this variable were collapsed into three. Those classes suitable for energy crop production are forested lands and lands that are open-pastures or marshes. The third class constitutes unsuitable lands: urban residential, extractive, urban and non-residential, transportation, cultivated, and water. Although some cultivated lands could be used for energy crops this conversion is not expected. Therefore cultivated lands are assigned to the unsuitable class together with the developed uses.

This constraint removed 8.1 million acres of wet mineral soils and half a million acres of peatlands from the inventory of suitable wetlands.

Drainage

Agricultural drainage is a common practice on wet soils. To further refine the category of open-pasture lands, considered suitable for energy crops, this variable must be considered. Open-pasture lands that have been artifically drained are generally agricultural lands, used for livestock grazing and forage crops. These uses are more profitable than growing energy crops and so this category of land was excluded in the analysis.

When the artificial drainage constraint was applied on top of the land use constraint the picture of available wetlands for energy crops was considerably changed (see Figure 2). Most of the wetlands in southern and western Minnesota have now been excluded. These lands, now drained, are producing agricultural crops at a rate exceeding few places in the world. As compared with Figure 1, the land use and drainage constraints have most affected the wet mineral soils (reduced by 72 percent to 3.5 million acres). Only 11 percent of the peatlands were affected, so that 5.2 million acres of peatland remain available. In total, a significant 8.7 million acres, or 16 percent of the state, remains in its wet natural state. These wetlands are concentrated in the north and north-central parts of the state.*

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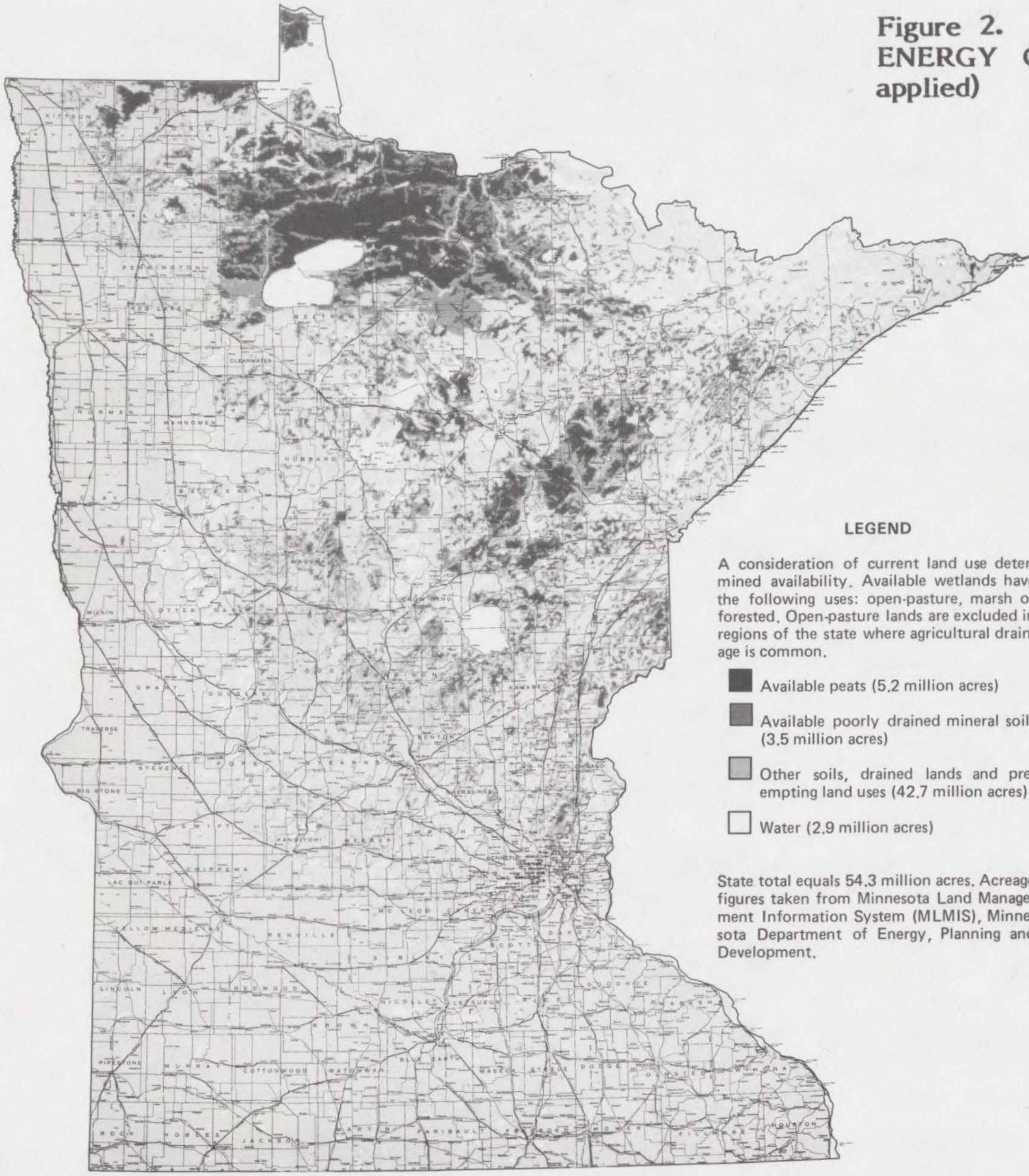
*See Appendix A for a county-by-county listing of these wetlands.

Figure 2. BASE MAP OF WETLANDS AVAILABLE FOR ENERGY CROPS (land use and drainage constraints applied)



LEGEND

A consideration of current land use determined availability. Available wetlands have the following uses: open-pasture, marsh or forested. Open-pasture lands are excluded in regions of the state where agricultural drainage is common.

- Available peats (5.2 million acres)
- Available poorly drained mineral soils (3.5 million acres)
- Other soils, drained lands and preempting land uses (42.7 million acres)
- Water (2.9 million acres)

State total equals 54.3 million acres. Acreage figures taken from Minnesota Land Management Information System (MLMIS), Minnesota Department of Energy, Planning and Development.

DISCUSSION OF OTHER FACTORS

Forest Cover

The majority of wetlands currently suited for the production of energy crops are forested. Black spruce dominates the peatlands while aspen and birch are most common on wet mineral soils. Both these trees are important to the timber industry of northern Minnesota. Since deforestation would be a preliminary step in developing any wetlands, the forest cover must be thoroughly considered. Analysis showed that 62 percent of the peatlands suitable for energy crops are covered with timber having commercial value. Similarly, 74 percent of the wet mineral lands are forested. One-third of the total wetlands are free of forest cover, presenting no land use conflict with the timber industry.

Land Ownership

Who owns the wetlands? is a critical question in considering the likelihood of developing an energy crop industry. The lands best suited for energy crops were compared with the MLMIS data base on land ownership. Categories of land ownership (ninety-nine) were collapsed into five major groups. Table 1 shows the results of this analysis.

Table 1. OWNERSHIP OF LAND SUITED FOR ENERGY CROPS

	Peatlands		Wet Mineral Soils		Total	
Owner	Acres	Percent	Acres	Percent	Acres	Percent
Government						
Federal	400,000	7.7	140,000	3.97	540,000	6.2
State	2,480,000	47.6	830,000	23.5	3,310,000	37.9
County & Local	600,000	11.5	420,000	11.9	1,020,000	11.7
Indian	280,000	5.4	190,000	5.4	470,000	5.4
Private	1,450,000	27.8	1,950,000	55.2	3,400,000	38.9
TOTAL	5,210,000	100	3,530,000	99.9	8,740,000	100.1

The State of Minnesota holds nearly 2.5 million acres of the suited peatlands (about 50 percent of the total). These lands include about 1 million acres which are non-forested or covered with non-productive timber. It is these open peatlands that could easily lend themselves to energy crops. Privately-owned peats account for 1.5 million acres or about 30 percent of the suitable peatlands. The private sector controls 55 percent of the wet mineral lands (nearly two million acres) but the state is the second major holder of these lands with 830,000 acres (about 25 percent).

Overall, the state and the private sector are the primary owners of the land best suited for energy crops, administering 3.3 million and 3.4 million acres respectively. The state's share is about 38 percent of the wetlands and 48 percent of the peatlands, a markedly different figure than the 90 percent commonly mentioned for state-owned peat. Using these lands for energy crops need not necessarily conflict with either the use of peat for energy or with the timber industry. If the land resources are well used, peat mining and cash timber crops can both be taken before energy crops are begun.

Constraints on Wetland Availability

Figure 2 presents a base map indicating where the wetlands are in Minnesota that are best suited for energy crops. Locating the wetlands is a starting point, it does not guarantee that they will be available when the time comes to actually begin planting and harvesting energy crops. Other forces must be considered, particularly land use conflicts and economic limitations.

Because bioenergy research is new in the United States, it is not know what factors will actually present constraints on land availability. Internal discussions at the University of Minnesota generated an initial list of possible conflicts and restrictions. The problem was then discussed with a large number of public planners, technicians, and policy makers in order to expand and refine the list. During these discussions, participants were also asked to indicate the geographic extent of each constraint. Through these discussions we were able to refine our list of constraints while at the same time making contacts and building a constituency within those departments and agencies which may eventually be involved in the growth of energy crops as a new industry in Minnesota.

The final list of possible constraints is divided into two types: land use conflicts and economic limitations (see Table 2). To examine all these factors on a statewide basis would be an extremely difficult and time-consuming task. Representative study areas were, therefore, chosen where these constraints could be individually and collectively studied as to how they would affect the availability of wetlands. This pilot study should provide a strong base from which similar county, regional, or statewide investigations could commence.

Table 2. POSSIBLE CONSTRAINTS ON AVAILABILITY OF WETLANDS FOR ENERGY CROPS

Land Use Conflicts		Economic Limitations
• human settlement	• unique natural areas	• productivity
• commercial forestry	• historic sites	• water access
• expansion agriculture	• potential mineral reserves	• road access
• outdoor recreation	• commercial peat mining	• access to agriculture
• wildlife	• land ownership	• management unit size

2. AITKIN COUNTY

Aitkin County in north-central Minnesota was chosen for the first of two pilot studies (see Figure 3). Of all the counties with large wetland acreages, it is closest to the Twin Cities. Both state government personnel and University researchers were familiar with the area and would be most able to give advice and react to results. Aitkin County presents a variety of potential land use conflicts with energy crops but it also contains a major development of wetlands for paddy-grown wild rice, which may prove to be similar to bioenergy farming.

Methods used for analyzing available wetlands in Aitkin County were similar to those used in preparing the base map of Minnesota wetlands. Again the computer capabilities of MLMIS were used. Maps were produced to show the areas of the county that are affected by each possible constraint. Figures were generated to show how these areas interface with the wetlands available for energy crops. And, finally, composite maps were prepared to show where land would be available under various development models.

THE STUDY AREA

Much of Aitkin County was once covered by the glacial lakes Aitkin and Upham whose basins now hold

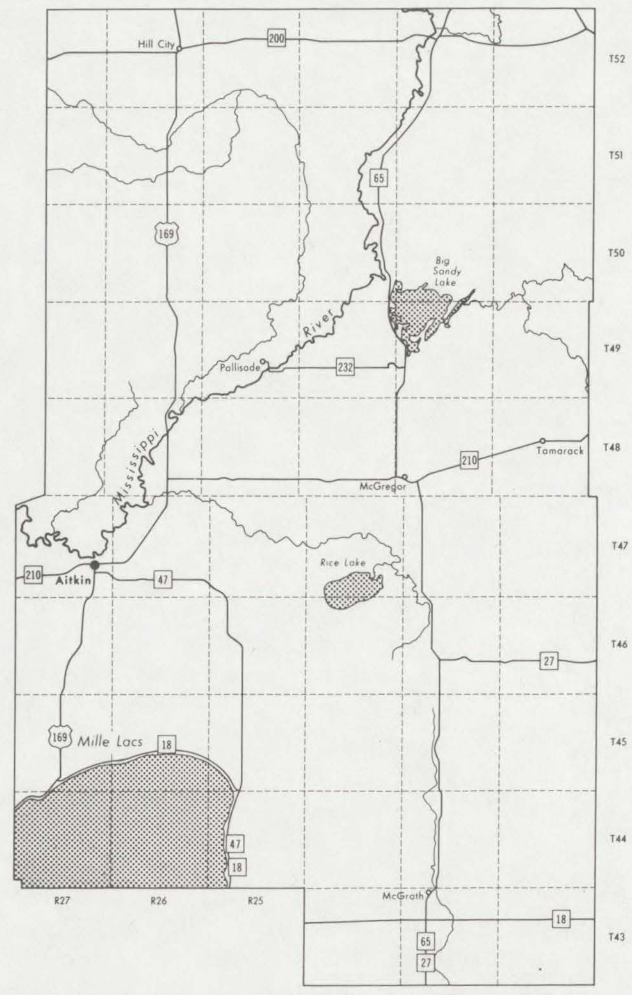
Figure 3. PILOT STUDY AREA--AITKIN COUNTY

extensive deposits of peats and associated poorly drained mineral soils. The Mississippi River flows through these wetlands; entering the county from the northeast and leaving in the west near the town of Aitkin (Figure 4). The southwest corner of the county is covered by Lake Mille Lacs, one of the largest water bodies in the state, supporting nationally famous sport fishing. Other significant lakes include Big Sandy, a major recreational attraction, and Rice Lake, within the Rice Lake National Wildlife Refuge.

Aitkin County encompasses nearly 1.3 million acres of land and water. About 70 percent of the county is forested and 20 percent used for agriculture, with hay and other forage crops as the principal farm products. Aitkin County is the state's leader in production of wild rice (nearly 30 percent of the state total in 1977). About 75 percent of this yield is grown on carefully managed paddies covering more than six thousand wetland acres.

Population in the county was more than 13,000 people in 1980, an 18 percent increase over 1970. About 80 percent of the labor force is employed in manufacturing and sales, the remaining 20 percent are in agricultural and timber-related industries. The town of Aitkin is the largest municipality in the county and is the

Figure 4. MAJOR PHYSICAL AND CULTURAL FEATURES OF AITKIN COUNTY



county seat. With its population of 1,770, it is the major trade center for the county.*

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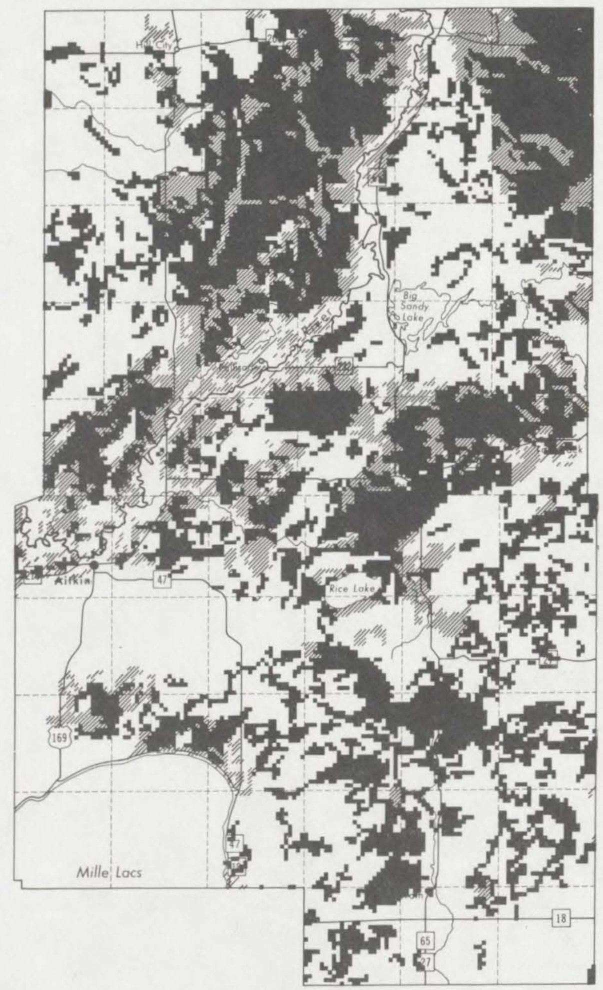
*Population figures were obtained from the 1980 Census. The labor information was taken from Borchert and Gustafson, Atlas of Minnesota Resources and Settlement, Minneapolis, Center for Urban and Regional Affairs, University of Minnesota and Minnesota State Planning Agency, 1980.

THE WETLAND BASE

Nearly half of Aitkin County is covered with wetland: approximately 445,000 acres of peatland and 179,000 acres of wet mineral soils. Of the five types of peat recorded in Aitkin, 90 percent are acid peat (with a pH level of less than 5.2). The wet mineral soils consist of poorly drained sands (40 percent), clays (25 percent) and loams (35 percent).

Wetlands improved for agriculture, transportation, extractive or developed purposes were excluded from the wetland base.* This left 96 percent of the peat soils (292,300 forested acres and 135,000 acres of open-pasture and marsh) and 80 percent of the wet mineral soils (103,200 forested and 38,000 open-pasture and marsh)--568,500 acres in total. Figure 5 displays the resulting base map of wetlands in Aitkin County. The largest deposits of peat are in the northern stretches of the county on the poorly drained glacial lake basins. Wet mineral soils predominate along the Mississippi River and in small deposits adjacent to the large peatlands.

Figure 5. BASE MAP OF WETLANDS AVAILABLE FOR ENERGY CROPS IN AITKIN COUNTY (land use and drainage constraints applied)



▬ Peat soils

/// Wet mineral soils

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*"Current" land uses were determined from the MLMIS 1969 Land Use Map.

LAND USE CONFLICTS

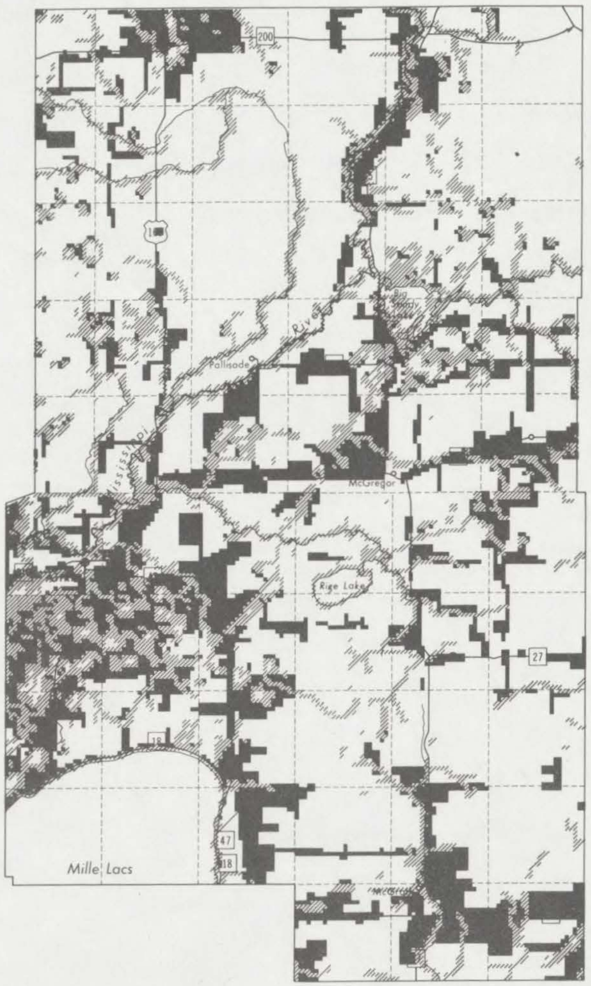
In this section and the next the impacts of various constraints on wetland availability will be examined. The constraints presented here were listed at the end of the section on Minnesota's wetland base. In each case we assume that the constraint is completely binding. While this may not be entirely realistic it is a good way of showing the relative effect of each constraint on the wetlands that could be used for energy crops. Both land use constraints and economic constraints are explored. In each case a map shows which of the county lands are affected by the constraint and figures are presented to show how these county lands interface with the areas of the county included in the wetland base. A final section of this chapter will discuss the overall findings and present a composite analysis of how the wetlands in Aitkin County might be used for bioenergy development under a variety of development models.

Human Settlement

The citizens and government of Aitkin County have determined which areas of the county they wish to preserve for human settlement. Their plan, embodied in the county zoning ordinance and zoning maps, sets aside two areas for human settlement: farm-residential and shoreland. Within these areas, conditional use permits are required for constructing facilities such as dams, reservoirs, and canals--facilities that may be essential in biomass operations. The ordinance and zoning maps were prepared before anyone seriously considered biomass development, so constraints might be much smaller than those shown in Figure 6. Undoubtedly, the nature and scale of any proposed bioenergy operation will influence the county decision on how zoning will be applied.

If no development were allowed in these zoning districts 126,700 wetland acres (61,500 because of farm and residential zoning and 65,200 because of shoreland zoning) would be unavailable for energy crops. This represents 22 percent of the wetland base in Aitkin County.

Figure 6. HUMAN SETTLEMENT: LAND AFFECTED BY ZONING RESTRICTIONS



- Farm and residential

/// Shoreland

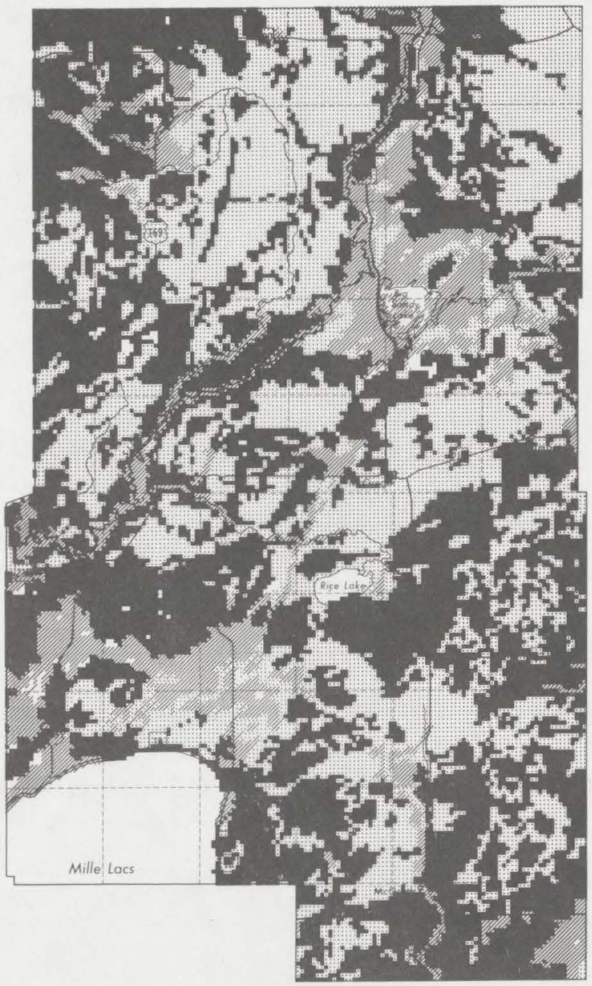
Commercial Forestry

Approximately 65 percent of Aitkin County is forested, including 70 percent of its wetlands. Commercial forestry is an important industry in this county and since deforestation is a preliminary step in preparing wetlands for bioenergy purposes the timber productivity of these lands must be considered. The commercial value of existing stands and the lands used to grow such timber are influenced by a wide range of variables including tree type and density, accessibility, soil productivity, and distance to market.

Of the various factors the Minnesota Department of Natural Resources would like to use for rating forest land, only a variable indicating the productivity of the soil for trees is currently available county-wide. This variable was used, therefore, for this analysis. The application of soil productivity alone, however, does not adequately address commercial forest suitability. It is only one of several important factors. Furthermore, forest productivity is keyed to the single tree specie which typically thrives best on a given soil. Commonly, the existing trees are not the type for which the productivity ratings have been generated. The ratings, therefore, cannot be used to evaluate most existing stands though they do provide a general insight into the capability of the soil to produce selected timber crops.

Figure 7 shows the DNR ratings for forest productivity. If only the most productive soils for timber growth were removed from the wetland base, 141,200 acres (or 25 percent of the base) would be unavailable for energy crops. This acreage is completely on wet mineral soils. An additional 427,300 acres of peatlands are rated low in productivity for commercial forests.

Figure 7. COMMERCIAL FORESTRY: SOIL PRODUCTIVITY FOR TIMBER GROWTH



- High
- Moderate
- Low

Expansion Agriculture

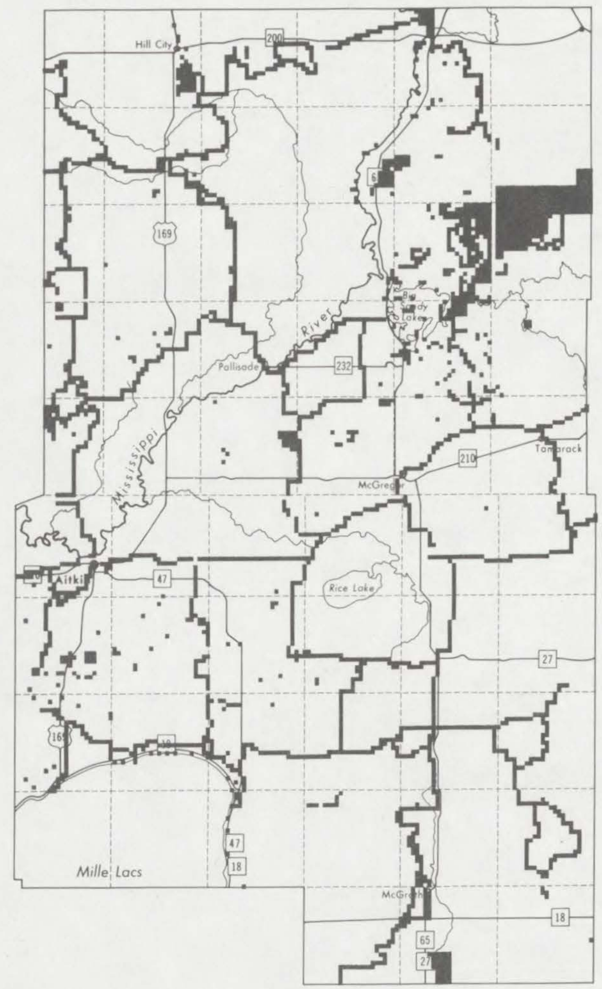
The potential for expanding agricultural lands is difficult to address in Aitkin County and for this reason no estimate could be made of the size of this constraint. The Census of Agriculture shows a nineteen percent increase in Aitkin County's cropland between 1969 and 1978. It could be theorized that lands adjacent to existing cropland are those likely to be developed for agricultural purposes. This concept may be operating to some extent in Aitkin County, but a major portion of the raw land being improved for agriculture is being done so by a single entrepreneur. Much of this large scale conversion (about 5,000-10,000 acres) is occurring on large blocks of wetlands that are quite removed from traditional farming operations. Because of this; the potential for expansion agriculture seems unpredictable. Abandoned farmlands lying near or adjacent to overgrown drainage systems are also potential candidates for cropland conversion. A change in farming economics could bring these lands, which lie mainly in the northern half of the county, back into production.

While not necessarily true for Aitkin County, the theory that privately-held lands adjacent or accessible to existing farms and abandoned farmland are those most likely to be improved for agriculture is a sound concept. However, it is these same lands that might best be used for energy crops if energy farming were to be incorporated into existing agriculture.

Outdoor Recreation

Outdoor recreation, on the other hand, has a constituency that probably would contest the conversion of "their land" to another use. The Department of Natural Resources maintains an inventory of all recreation facilities in the state. The State Comprehensive Outdoor Recreation Plan (SCORP) includes campgrounds; trails for hiking, cross-country skiing, and snowmobiling; wildlife management areas; athletic fields; water accesses; state, county, and local parks; and state forests recommended for recreation. These existing recreation lands are shown in Figure 8. They overlay 50,900 acres of the wetland base in Aitkin County. If they were excluded from land available for energy crops 9 percent of the wetland base would be lost: 38,300 acres of peatland and 12,600 acres of wet mineral soils.

Figure 8. OUTDOOR RECREATION: LAND CONTAINING PUBLIC AND PRIVATE RECREATIONAL FACILITIES



▬ Recreation lands

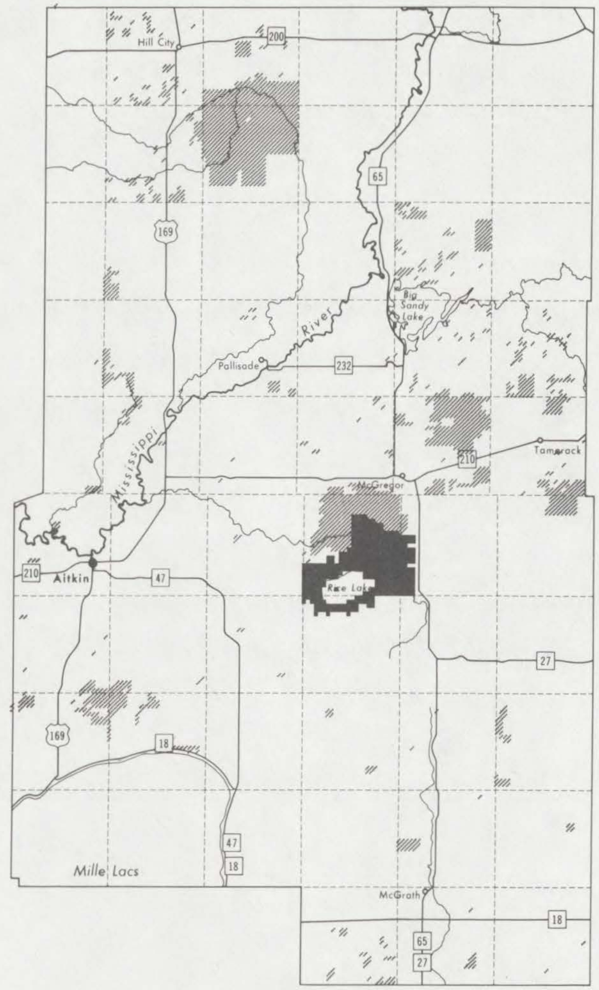
Wildlife

Development of energy crops on wetlands may not be compatible with wildlife management practices. For example, cattails rate as poor nesting cover and food source for waterfowl. Also, the practices used to control water levels for energy crops may be inconsistent with wildlife needs.

Many state and federal wildlife areas exist in Aitkin County, set aside as either state or federal refuges. No private lands, regardless of their wildlife use or potential, were considered in this analysis.

Federal and state wildlife areas cover a total of 87,000 acres (15,000 federal acres and 72,000 state acres). The distribution of these lands is shown in Figure 9. If all wildlife areas were excluded from the wetland base 12 percent of the base or 68,000 acres would be unavailable for energy crops (56,500 acres of peat and 11,500 acres of wet mineral soils). This includes the 11,200 acres of wetlands within the Rice Lake National Wildlife Refuge.

Figure 9. WILDLIFE: LANDS MANAGED OR RECOMMENDED FOR WILDLIFE



Federal wildlife lands

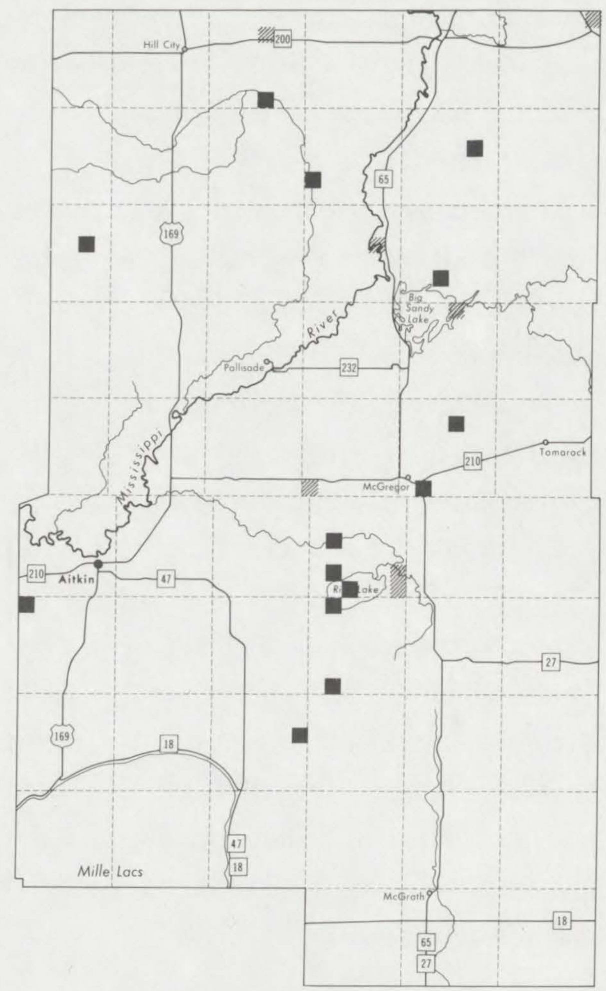
/// State wildlife lands

Unique Natural Areas

Aitkin County contains a number of rare or unique plant and animal communities. The Minnesota Natural Heritage Program is cataloging areas that contain unique natural features. To date, the program has identified unique natural sites within 21 different one mile sections of Aitkin County. These sites include nesting areas for colonies of herons and comorants, established territories for eagles and other rare birds, unique peat bogs and related plant communities, and unique stands of hard and softwood trees. Figure 10 shows the location of these sites, covering an area of about 13,500 acres when the entire 640 acre section around each is included.

If these sites were removed from the available wetlands base, 7,400 acres would be excluded or about 1 percent of the entire wetland base. This includes 2,000 acres of lands with unique plant communities (all but 200 acres on peatlands) and 5,400 acres with unique animal communities (all but 500 acres on peatlands).

Figure 10. UNIQUE NATURAL AREAS: LANDS CONTAINING UNIQUE PLANT AND ANIMAL COMMUNITIES



Animal communities

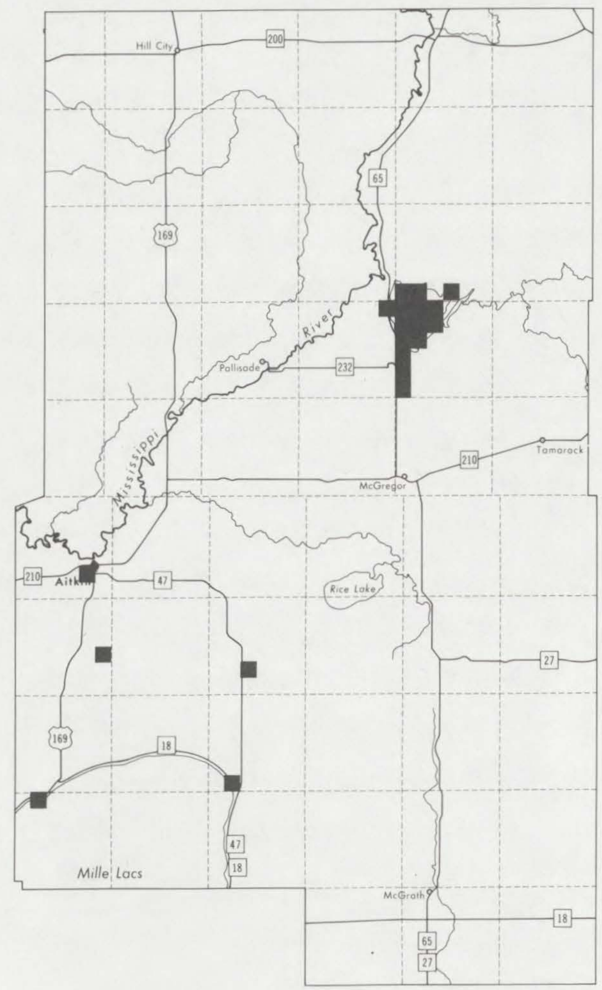
Plant communities

Historic Sites

Also worthy of preservation are historic sites containing important cultural artifacts. The Minnesota Historical Society projects that as many as one to two thousand important sites may exist in Aitkin County. To date, however, fewer than fifty archaelogical sites have been identified--a fact attributed to this county's expanse of undeveloped land. All of the identified sites are prehistoric Indian burial mounds. In order to prevent disclosure and possible pilfering, the Minnesota Historical Society prefers to present only generalized maps of the location of these sites. The entire 640 acre section around each of these sites is, therefore, recorded in Figure 11. Twenty sections are shown containing 12,800 acres of land.

If the entire section containing historic sites were excluded from lands available for energy crops 1,400 acres would be affected--less than 1 percent of the entire wetland base. The bulk of these sites (1,000 acres) are on wet mineral soils. The Historical Society would want the opportunity to search for unknown historic sites within any area proposed for biomass development.

Figure 11. HISTORIC SITES: LANDS CONTAINING PREHISTORIC INDIAN BURIAL GROUNDS



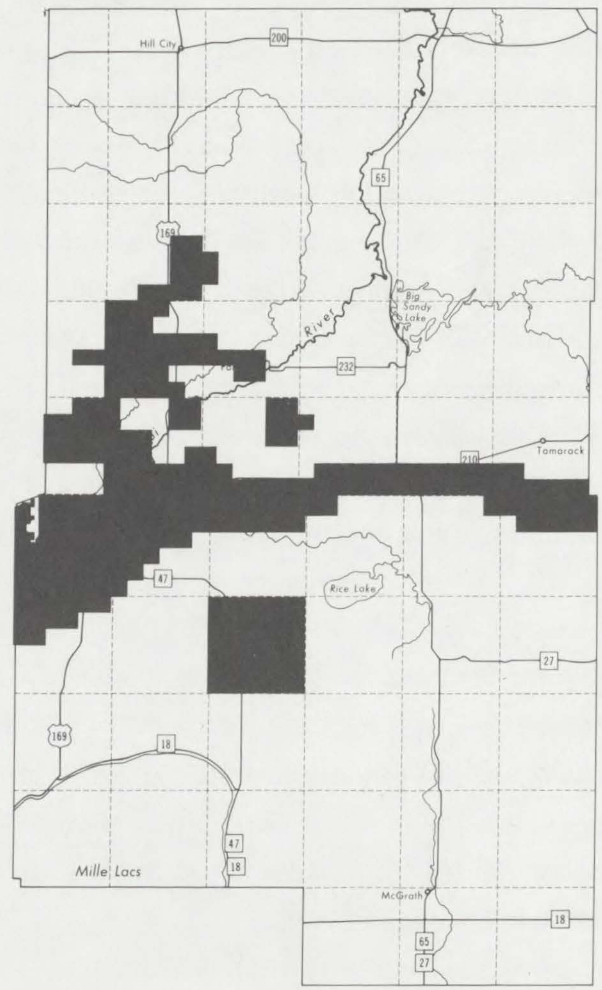
▬ Historic sites

Potential Mineral Reserves

In the future, mining might present a land use conflict with energy crops. At present, no mining for minerals is underway in Aitkin County. The Minerals Division of the Minnesota Department of Natural Resources states that iron, manganese, and sulfur deposits do exist in Aitkin County but under current technology mining cannot be economically justified. For this reason, surveying and mapping of the potential resource has not been precise. Figure 12 presents a rough map of the possible extent of geologic formations which may contain significant deposits of these three minerals--about 174,000 acres in total, including the Aminikie Group with its possible iron and manganese deposits and the Glen Township Formation of the Mille Lacs Group which holds known reserves of sulfur.

If all of these lands that overlap with the wetland base were removed from consideration, 82,600 acres of wetland base or about 14 percent would be unavailable for development (56,000 acres of peatland and 26,600 acres of wet mineral soil).

Figure 12. MINERALS: LANDS CONTAINING POTENTIAL MINERAL RESERVES



▬ Potential mineral reserves

Commercial Peat Mining

Minnesota's extensive peatlands are being viewed as a potential source of future energy. The Minnesota Peat Project at the Minnesota Department of Natural Resources is conducting inventories and related research on Minnesota's peatlands. This includes a study of the peatland characteristics which might make them attractive for energy development. Two conditions which have been identified are that peatlands should have a minimum depth of five feet and that sphagnum peat should not be considered because of its low BTU content and high value for horticultural applications.

Peat extraction and energy crops may be compatible industries. Development for energy crops, it is currently believed, may occur on landscapes where a layer of peat has been previously removed. If some peat remains and water levels are maintained, energy crops could be a natural second step for these lands. The feasibility of this dual approach, however, was ignored at this stage of the analysis. Based on the Minnesota Soil Atlas, we found most of the peatlands in Aitkin County to be at least five feet deep and not sphagnum peats.

Figure 13 presents the peatlands suitable for commercial mining. Ninety-nine percent of the county's peatlands (426,100 acres) are included.* If these peatlands are excluded from the wetland base, 75 percent of the base would be unavailable for energy crops.

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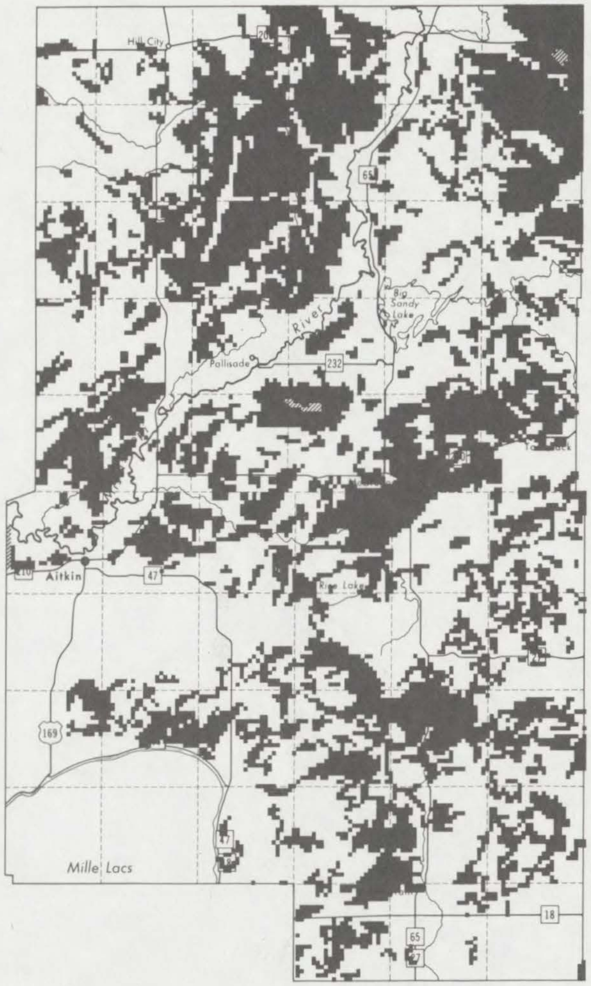
*Scattered field tests by the Minnesota Peat Project have subsequently indicated that peats in Aitkin County are not as deep as originally projected.

Figure 13. PEATLANDS SUITED FOR COMMERCIAL MINING



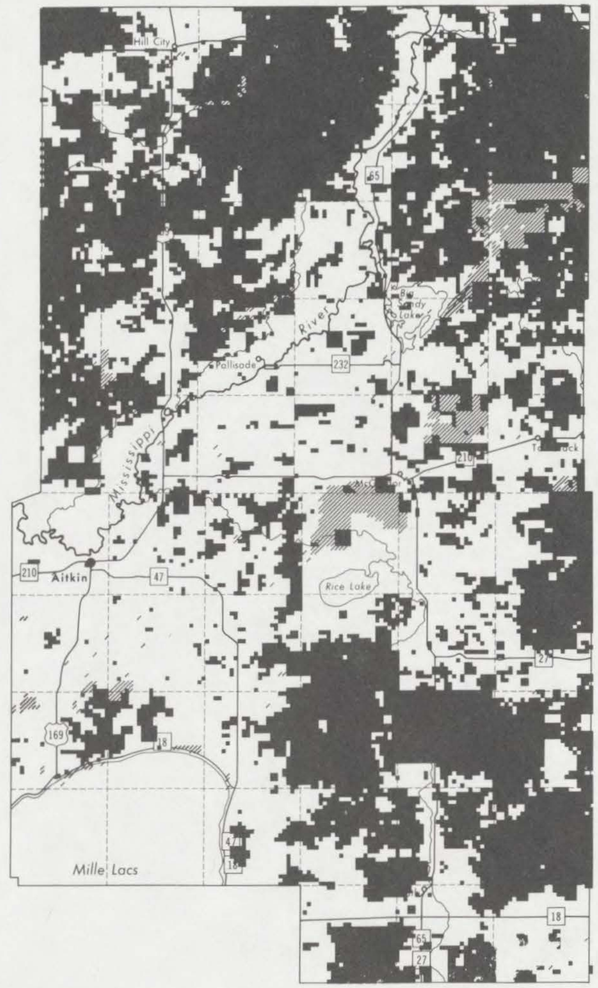
- Suited peatlands
- Non suited peatlands

Land Ownership

Ownership of lands that might be used for energy crops will probably have a major effect on whether or not they are developed. Some owners may refuse to let their lands be used. MLMIS ownership records indicate that half of the land in Aitkin County is privately owned (this includes Indian land), 31 percent is owned by the state, 18 percent by the county, and 1 percent by the federal government. When only the wetland base is examined, however, we find that the state owns 48 percent, private individuals 34 percent, the county 16 percent, and the federal government 2 percent.

Though the state and county own many wetlands, not all of these are available for energy development. The Minnesota Peat Project has identified state and county lands that may be available for developmental leases. These are shown in Figure 14. Approximately 341,600 acres of state and county wetlands were judged leasable (288,400 acres of peatland and 53,200 acres of wet mineral soils). This represents about 93 percent of state and county owned wetlands and 60 percent of the wetland base. No limitations on the availability of federal or privately owned wetlands are examined here. If state and county lands not available for lease are excluded from the wetland base 24,500 acres or 4 percent are lost for energy crop development.

Figure 14. LAND OWNERSHIP: STATE AND COUNTY-OWNED LANDS THAT ARE POTENTIALLY LEASABLE



▬ Leasable state and county lands

/// Other state and county lands

ECONOMIC LIMITATIONS

In addition to the ten land use constraints just examined, five economic restrictions were also explored.

Productivity

The inherent capability of the wetlands to produce energy crops (such as cattails) is an important economic consideration. Some wet soils are naturally more productive than others. A general index of expected productivity for herbaceous plants is shown in Table 3. These estimates, however, are preliminary as research on wetland productivity is still quite limited.

The wetland soils in Aitkin County fall mostly into moderate and high productive levels. High productivity is possible on 70,700 acres of the wetland base and moderate productivity on 441,500 acres. If low productivity soils are excluded from the wetland base, 56,300 acres or 10 percent of the base is unavailable for energy crops (1,200 acres of peat and 55,100 acres of wet mineral soils). Figure 15 shows the distribution of various wetland soils by productivity across the country.

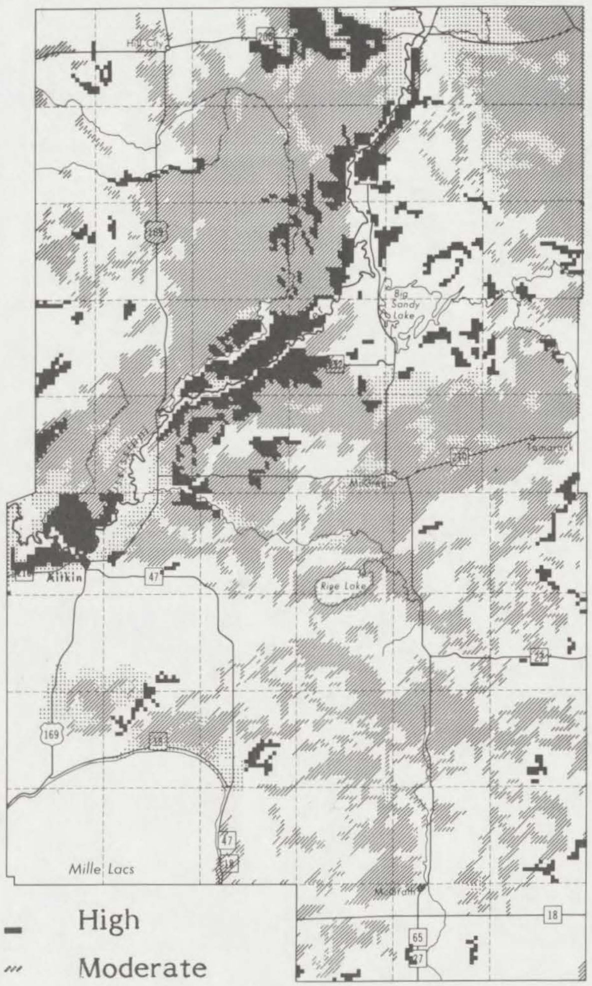
Table 3. PRODUCTIVITY OF WETLAND SOILS

High	Moderate	Low
• non-acid peat*	• acid peat**	• shallow peats (over sand)
• Poorly drained clays	• peats (undifferentiated)	• raised bog peats (sphagnum)
	• poorly drained loams	• poorly drained sands

* Non-acid peats have pH values greater than 5.2.
**Acid peats have pH values of less than 5.2.

Source: Rouse Farnham, Department of Soil Science, University of Minnesota.

Figure 15. PRODUCTIVITY: PROJECTED SOIL YIELDS FOR HERBACEOUS PLANTS



High

Moderate

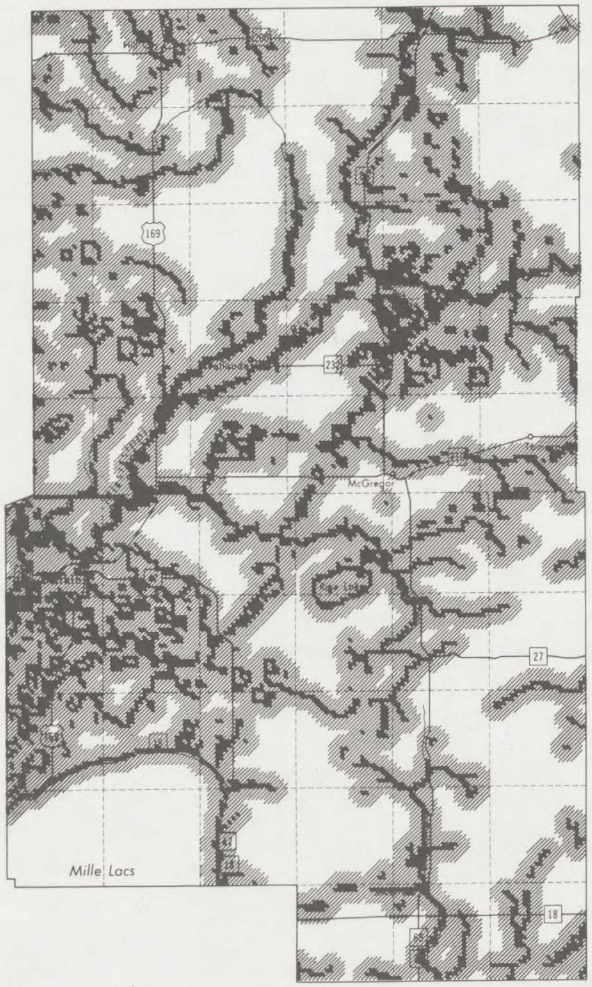
Low

Water Access

The geographic relationship of wetlands to permanent (as opposed to seasonal) lakes, rivers, and streams is significant if energy crops such as cattails are to be grown in paddies like cultivated wild rice. For rice, a ready source of water is needed for flooding the crop during the growing season and a drainway required for subsequent discharge prior to harvest. Adjacent waterways are commonly used for flood water and drainage purposes. It is still unclear whether plants such as cattails can be grown and harvested in pools of standing water or whether they are better managed in "flood and drain" paddies. Because water access could be a major limiting factor in a paddy system, the issue was addressed in this analysis.

Wetlands within one mile of permanent lakes, rivers, or streams were considered more usable than more remote wetlands. Figure 16 shows the proximity of all the land in the county to permanent waterways. It is important to note that the State of Minnesota carefully regulates the water use from public lakes and rivers. Waterways included here may not necessarily be used for flooding and draining. When access to water is combined with the wetland base, we find that 44 percent of the base or 252,900 acres would be excluded if all wetlands farther than one mile from a waterway are found to be too costly to use in growing energy crops. This includes 211,900 acres of peatland and 41,000 acres of wet mineral soils that fall outside the one mile limit.

Figure 16. WATER ACCESS: PROXIMITY TO PERMANENT LAKES, RIVERS, AND STREAMS

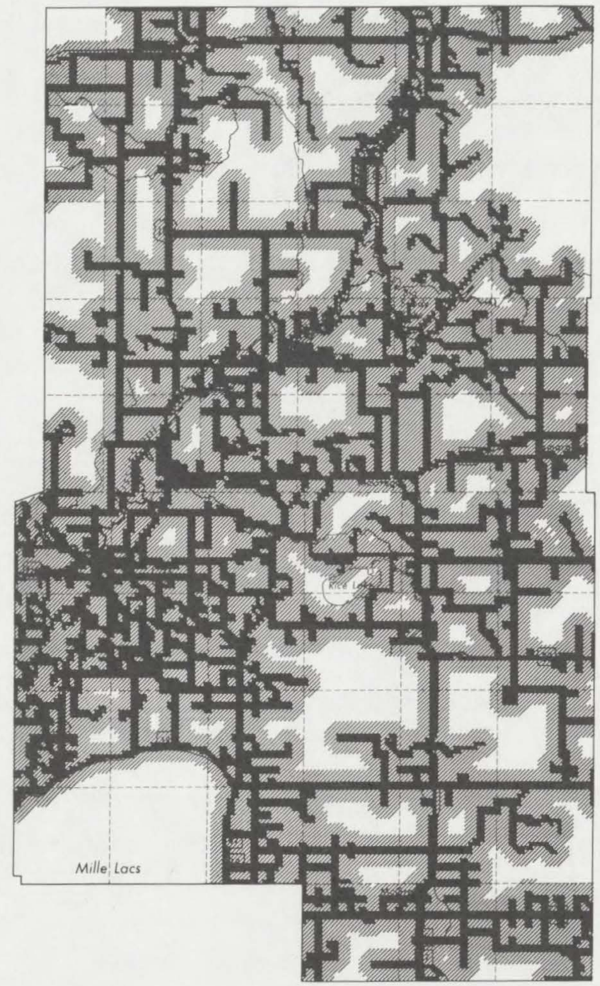


- ▬ Lands adjacent to permanent water
- /// Lands within one mile of permanent water

Road Access

Existing transportation networks provide efficient means for moving in equipment during construction of energy croplands and for transporting the harvest. The cost of building new roads could be a prohibitive obstacle to developing these croplands. In this analysis, wetlands within a mile of public road networks were considered to have a substantial advantage over less accessible wetlands. All lands with close access to public roads are located in Figure 17. About three quarters of the wetland area have good road access. If wetlands further than one mile from a public road are excluded from the wetland base 150,800 acres or 27 percent of the base is no longer available for energy crops--135,200 acres of peatlands and 15,600 acres of wet mineral soils.

Figure 17. ROAD ACCESS: PROXIMITY TO PUBLIC ROADS



▬ Lands adjacent to roads

/// Lands within one mile of roads

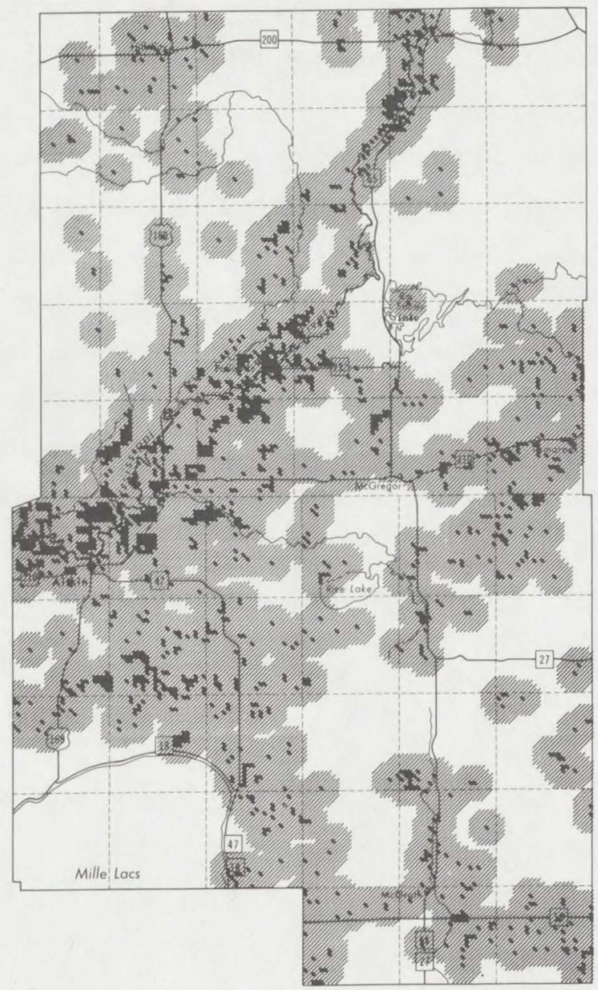
Access to Agriculture

One current development strategy is that energy crops might be economically grown if they were incorporated into private farming operations. Expensive machinery commonly used in traditional agriculture might also be employed for the energy farming, thus saving large capital outlays for equipment. Under this arrangement, energy crops would become an additional product of the local farming economy.

To explore this money saving option, we mapped all lands within one mile of cultivated land (see Figure 18). Cultivated lands were taken from the MLMIS 1969 Land Use Map. Although this map is biased against non-tilled farmlands and does not show the extent of recent agricultural development, it is a useful approximation of the general farming activities in Aitkin County.

If development of energy crops is limited to those wetlands within one mile of existing agriculture, 263,200 acres of the wetland base or 46 percent is eliminated from consideration--229,500 acres of peatland and 33,700 acres of wet mineral soils.

Figure 18. ACCESS TO AGRICULTURE: PROXIMITY TO CULTIVATED LAND



▬ Cultivated lands

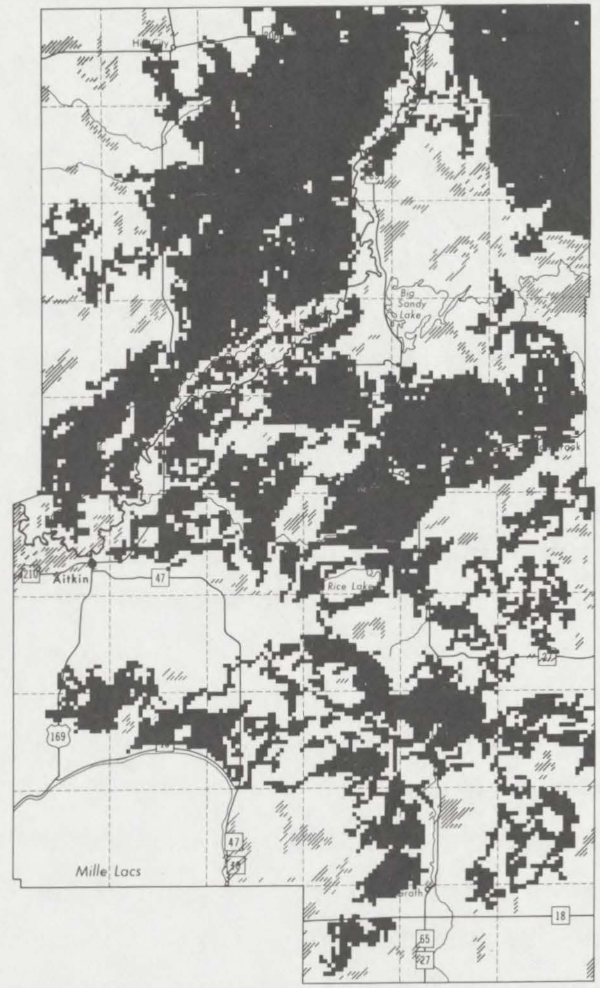
/// Lands within one mile of cultivation

Management Unit Size

An alternative development strategy might be large scale commercial development. In this case the developer would undoubtedly want a large wetland area that could be managed as a single unit. The minimum size of a viable management unit is unknown. One thousand acres might be the minimum economic size, but for this analysis we assumed that the developer would want room to expand and chose 4,000 acres as the unit size.* The distribution of management units of this size is mapped in Figure 19.

The large size of most of the wetland areas in Aitkin County means that even this large a management unit has little effect on restricting the availability of land for development. If development is restricted to management units of 4,000 acres or more, 48,000 acres or 8 percent of the wetland base is excluded--38,400 acres of peatland and 9,600 acres of wet mineral soils.

Figure 19. WETLAND MANAGEMENT UNITS



▬ Contiguous wetlands of more than 4,000 acres

/// Contiguous wetlands of 4,000 acres or less

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*In studies subsequent to this one, the size of the management unit was changed to 1,000 acres. If that unit size had been used here, nearly all 568,500 acres of the wetland base would have remained available for development.

SUMMARY OF CONSTRAINTS

The constraints considered here may not represent a complete list. And for each particular constraint the amount of wetland that would be affected may change as research continues and biomass development comes closer to being a reality. It may be that certain interests will conflict less or even more with plans to use these wetlands as the base of a new energy crop industry. Perhaps the need for new sources of energy will become important enough that biomass development will win out over many of the conflicts and limitations suggested by this list of constraints. In any case, this listing can serve as a starting point by indicating the obstacles that may be encountered in attempting to create an energy crop industry.

The constraints and their potential impact on limiting the amount of land available for energy crops are summarized in Table 4.

These constraints are not overwhelming. Six of the fifteen constraints affect 10 percent of the wetland base or less. Two of the remaining larger constraints, commercial forestry and commercial peat mining, may not be constraints at all since biomass development could follow as a subsequent use. County zoning (the human settlement constraint) would almost surely change to accommodate any proposed economic development. Mineral reserves pose no current constraint; though, if they ever became viable, they could quickly replace a surface use like biomass production. Of all the land use constraints, water access, road access, and access to agriculture, only protection of wildlife poses an irreducible constraint. The economic constraints are much larger and will affect development strategies.

These constraints cannot be added to estimate the total amount of wetland under constraint. Many of the individual constraints overlay each other. In the next section of this report, constraints are overlaid in four models of development strategy to determine how much land in Aitkin County might reasonably be available for biomass development.

Table 4. POSSIBLE CONSTRAINTS ON USE OF WETLAND BASE IN AITKIN COUNTY

Constraint	Acreage Affected Peatlands*	Wet Mineral Soils**	Total***	Percent
LAND USE CONFLICTS				
Human settlement	77,000	49,700	126,700	22
Commercial forestry	--	141,200	141,200	25
Expansion agriculture			?	?
Outdoor recreation	38,300	12,600	50,900	9
Wildlife	56,500	11,500	68,000	12
Unique natural areas	6,700	700	7,400	1
Historic sites	400	1,000	1,400	<1
Potential mineral reserves	56,000	26,600	82,600	14
Commercial peat mining	426,100	--	426,100	75
Ownership restrictions	18,700	5,800	24,500	4
ECONOMIC LIMITATIONS				
Productivity	1,200	55,100	56,300	10
Water access	211,900	41,000	252,900	44
Road access	135,200	15,600	150,800	27
Access to agriculture	229,500	33,700	263,200	46
Management unit size	38,400+	9,600+	48,000+	8+

*427,300 acres in total

**141,200 acres in total

***568,500 acres

+If 1,000 acre unit is used instead of 4,000 acre unit these figures would all be 0--no acreage affected.

WETLAND DEVELOPMENT STRATEGIES

The final stage of the analysis for Aitkin County involved a composite analysis of how the wetlands might be developed under four differing development strategies. Each strategy would bring different constraints into play. With the MLMIS capabilities for overlaying several factors on the wetland base map, we were able to see how different sets of limitations would affect the availability of land in each development model. This speculative process attempted to identify the wetlands that would be involved in each development strategy.

The first two models were largely applied in order to establish the limits of wetland development: in one no constraints are applied at all and in the other a maximum number of constraints is applied. These models serve to establish the minimum and maximum number of wetland acres available for development. In addition, two more likely development models were explored: one in which energy crops are developed as an extension of existing farm operations and one in which large commercial operations might occur as integral developments on their own.

In each case a model of what lands would be available is created by applying a specific mix of possible constraints. The constraints applied are presented in Table 5 and explained in more detail with the discussion of each model.

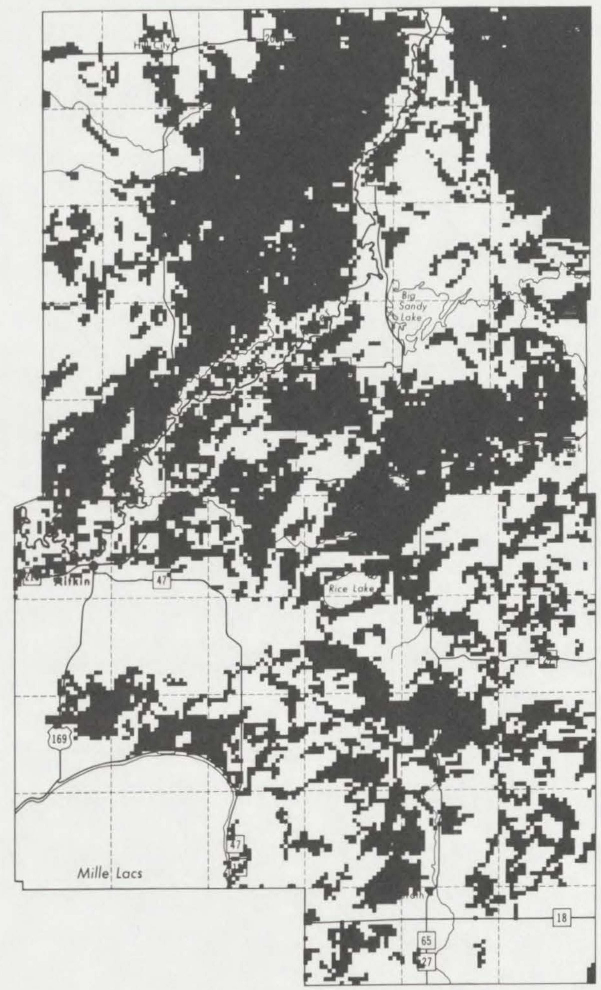
Table 5. CONSTRAINTS APPLIED IN WETLAND DEVELOPMENT STRATEGIES FOR AITKIN COUNTY

	MODEL			
Constraints	No Constraints	Maximum Constraints	Farm Development	Commercial Development
LAND USE CONFLICTS				
Human settlement		●		●
Commercial forestry				
Expansion agriculture				
Outdoor recreation		●	●	●
Wildlife		●	●	●
Unique natural areas		●	●	●
Historic sites		●		●
Potential mineral reserves				
Commercial peat mining				
Ownership restrictions		●	●	●
ECONOMIC LIMITATIONS				
Productivity		●	●	●
Water access		●		●
Road access		●	●	
Access to agriculture		●	●	
Management unit size		●		●

No Constraints Model

This strategy assumes that no economic limitations or land use conflicts will reduce the number of acres available for energy crop development. Though this strategy is unrealistic, it establishes the maximum amount of land available in Aitkin County: 568,500 acres of wetland, 75 percent peatland (427,300 acres) and 25 percent wet mineral soils (141,200 acres). Figure 20 displays the no constraints model. It is the same as the base map of available wetlands (Figure 5).

Figure 20. NO CONSTRAINTS MODEL: MAXIMUM AVAILABLE WETLANDS FOR ENERGY DEVELOPMENT



Suited wetlands

Maximum Constraints Model

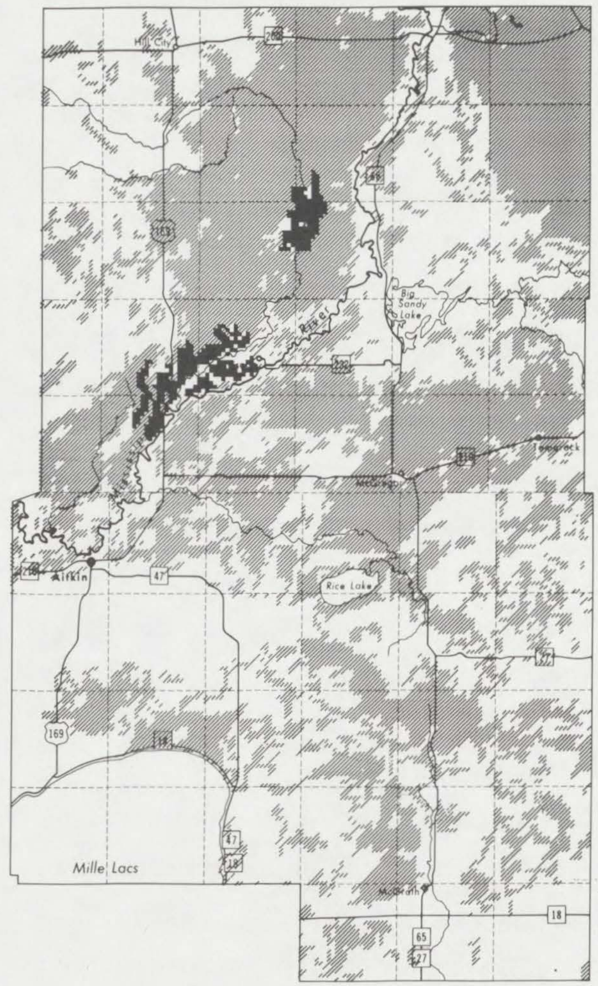
With this strategy all but four of the economic and land use constraints are applied. Again, the strategy is unrealistic, but it serves to establish the minimum amount of land that might be available for energy crops in Aitkin County.

Four factors were ignored in this strategy because of uncertainty as to how they would affect wetland availability. As already noted, the factors governing expansion agriculture in Aitkin County are unusual and therefore were not quantified in this analysis. For both commercial forestry and peat mining, energy crops could be a subsequent land use and so no conflict need exist. Mineral mining is not economically feasible now and there is no indication that it will be in the near future. All other constraints were applied and Figure 21 resulted.

The land available under maximum constraint amounts to 15,700 acres or about 3 percent of the wetland base--6,400 acres of peat and 9,300 acres of wet mineral soils.* These lands lie along the Willow River: one block in the north-central area of the county and another block near the river's junction with the Mississippi.

*If the management unit size, one of the economic limitations that was applied, is changed to 1,000 acres instead of the 4,000 acres assumed here, then the total amount of land available under maximum constraint likewise changes to 54,300 acres (10 percent of the wetland base)--31,200 acres of peat and 23,100 acres of wet mineral soils.

Figure 21. MAXIMUM CONSTRAINTS MODEL: MINIMUM AVAILABLE WETLANDS FOR ENERGY DEVELOPMENT



- Suited wetlands

''' Other wetlands

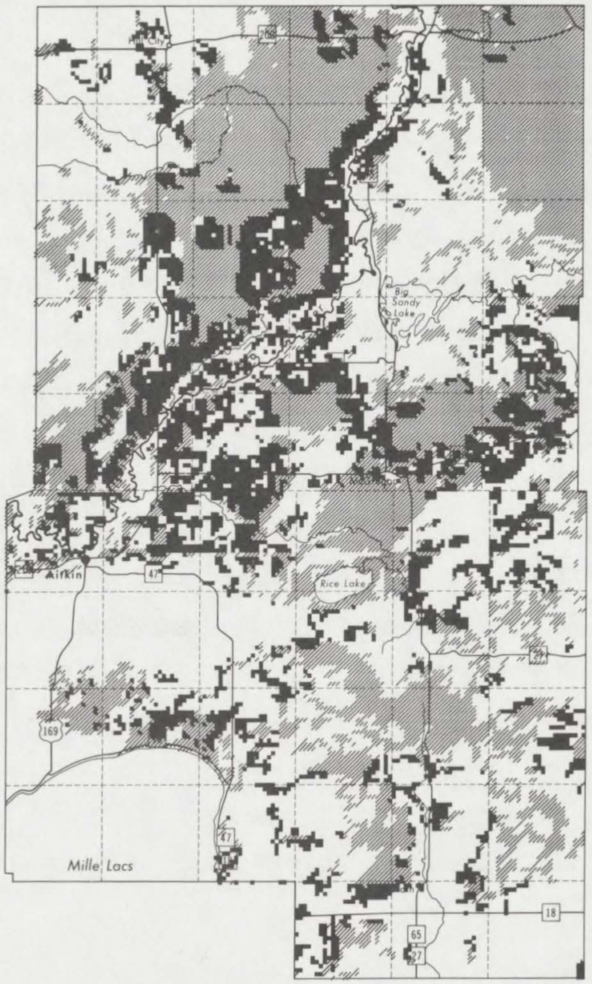
Farm Development Model

This model assumes that local farmers could be drawn in to manage and harvest wetland biomass. The labor and equipment from their farm operations would be applied to moderately or highly productive wetland areas within a mile of their existing farms. Small operators cannot afford to build their own roads, so access to already built road networks would also be important. Water access could probably be met through small, shallow wells and the extensive drainage ditch network found throughout the county. Large management units would be neither necessary nor desirable. As a consequence, the county would see no conflict with human settlement plans and any necessary conditional permits for development would be granted. Finally, the location and integrity of the historic sites could be entrusted to local inhabitants. The isolated Indian mounds could easily be skirted by farmers imposing virtually no reduction in available wetland acreage.

Under this strategy, the constraints that must be considered are four land use conflicts (outdoor recreation, wildlife, unique natural areas, and ownership restrictions) and three economic limitations (productivity, road access, and access to agriculture). When these constraints were applied, 205,000 acres remained available from the wetland base or 36 percent: 143,800 acres of peatlands and 61,200 acres of wet mineral soils. The distribution of these lands is shown in Figure 22. They are scattered throughout the county, but with a preponderance along the Mississippi River.

The restraint of access to agriculture accounts for the largest portion of the wetlands not available for this development model. If farmers could be persuaded to travel more than one mile from their present croplands to develop new energy crops, the quantity of land available for development would be markedly increased. Should small scale energy crops become profitable, farmers may elect to grow biomass exclusively and the constraint of closeness to agriculture may be eliminated. Some of the wetlands may prove to be too expensive for farmers to clear of existing cover. However, other wetlands smaller in size than the 600 acre minimum mapping unit used in this analysis, might be useful for small-scale farm development and compensate for these losses.

Figure 22. FARM DEVELOPMENT MODEL: WETLANDS SUITED FOR SMALL SCALE ENERGY DEVELOPMENT



▬ Suited wetlands

/// Other wetlands

Commercial Development Model

Large scale commercial development is a different kind of development strategy. Unlike the farming model, large plots are required: we assumed that they should be at least 4,000 acres. Water needs are extensive so access to a permanent river, stream, or lake is necessary. The large size means operations will undergo close scrutiny by the county and possibly development will not be allowed in areas currently zoned for human settlement. Enough capital will accompany these developments to overcome problems of road access and, obviously, access to existing farming operations is irrelevant. What will be relevant, however, is the preservation of historic sites. A large area around each site, perhaps as much as a section (one square mile), will be restricted from development.

The restraints applied for the commercial model, then, included six land use conflicts (human settlement, outdoor recreation, wildlife, unique natural areas, historic sites, and ownership restrictions) and three economic limitations (productivity, water access, and management unit size). The management unit size had to be applied a second time after all other constraints had been applied because we were looking, in the end, for large contiguous areas. Before this last restraint was applied, 30 percent of the wetland base remained available for development. But when the restriction to 4,000 acre management units was superimposed at the end, only 9 percent of the wetland base remained (51,300 acres)--36,600 acres of the peatlands and 14,700 acres of the wet mineral soils. These are distributed in four large blocks, as Figure 23 shows: one long section, straddling the Willow and Little Willow Rivers, another section adjacent to the Mississippi River in the north-central part of the county, and two sections in the south near the Snake River.

The severe reduction in lands available results because several constraints served to chop up large blocks of land. Water access was the single largest restriction, eliminating nearly half of the wetlands. Also significant were human settlement and outdoor recreation because their linear patterns dissected many potential large management units.

The quantity of wetlands available for development under commercial development strategy could be greatly increased if operators could use smaller management units.* Units could be in close proximity, if not contiguous. If the county saw benefits in commercial operations it could encourage development by quickly

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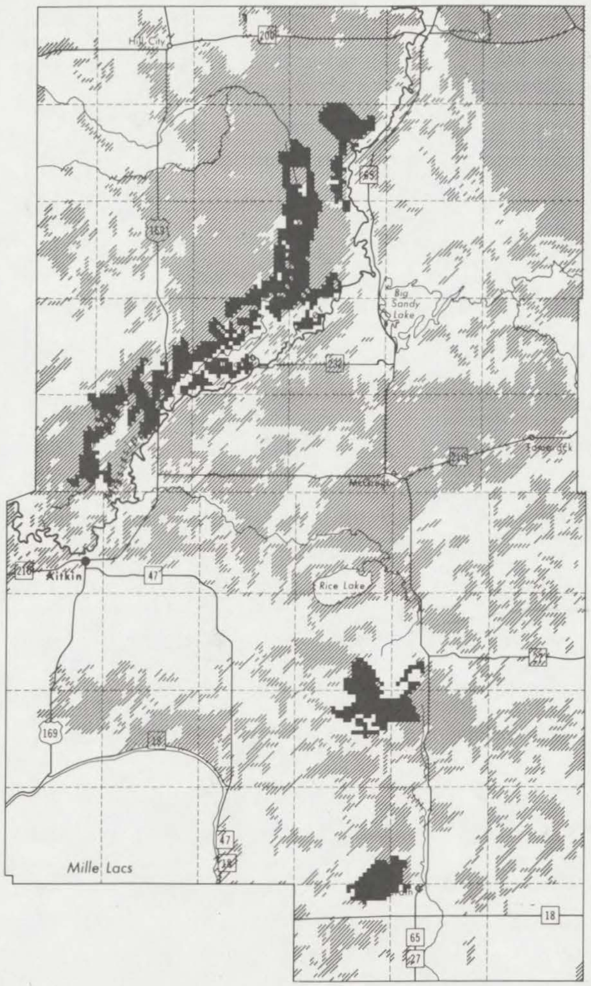
*If a 1,000 acre management unit size were used instead of the 4,000 acre unit, 19 percent of the wetland base would remain (104,500 acres)--14 percent of the peatlands (78,000 acres) and 5 percent of the wet mineral soils (26,500 acres).

Figure 23. COMMERCIAL DEVELOPMENT MODEL: WETLANDS SUITED FOR LARGE SCALE ENERGY DEVELOPMENT



- Suited wetlands

/// Other wetlands

processing and approving conditional use permits where precautions against abuse of land and neighbors had been guaranteed. Finally, if technology were developed for economic and efficient planting and harvesting of biomass without draining or flooding the area, significantly more land could be brought into production. Perhaps woody energy crops such as alders, willow, and aspen could be used in place of cattails. While cattails require flooding these woody energy crops do not.

It is also likely that both the farm model and the commercial model would be used in Aitkin County. Overall, about 225,000 acres or 40 percent of the wetland base is available if both development models are used.

CONCLUSIONS

The wetlands of Aitkin County hold tremendous potential for bioenergy. Although our development models imposed significant limitations on the wetland base, many acres are still suited for energy applications. The 205,000 acres produced through the farm model represents more than twice the land currently under cultivation in Aitkin County. The 51,700 acres produced through the commercial model represent only nine percent of the wetland base. This is, however, more land than is devoted to 150 average-sized Minnesota farms. About 60 percent (31,700 acres) of these commercially suited wetlands are state-owned. Using the 3,000 acre lease minimum limit established by the Minnesota Department of Natural Resources for state-owned peatlands, at least ten commercial ventures could operate within these guidelines in Aitkin County alone.

How typical is Aitkin County of the wetlands to be found elsewhere in the state? In western Minnesota the wetlands are generally small and occur in agricultural settings. In developing energy crops they would present quite a different picture than the large forested wetlands of Aitkin County. In order to present a balanced assessment of the energy crop potential in Minnesota, we turn next to an analysis of wetland availability in two counties of west-central Minnesota.

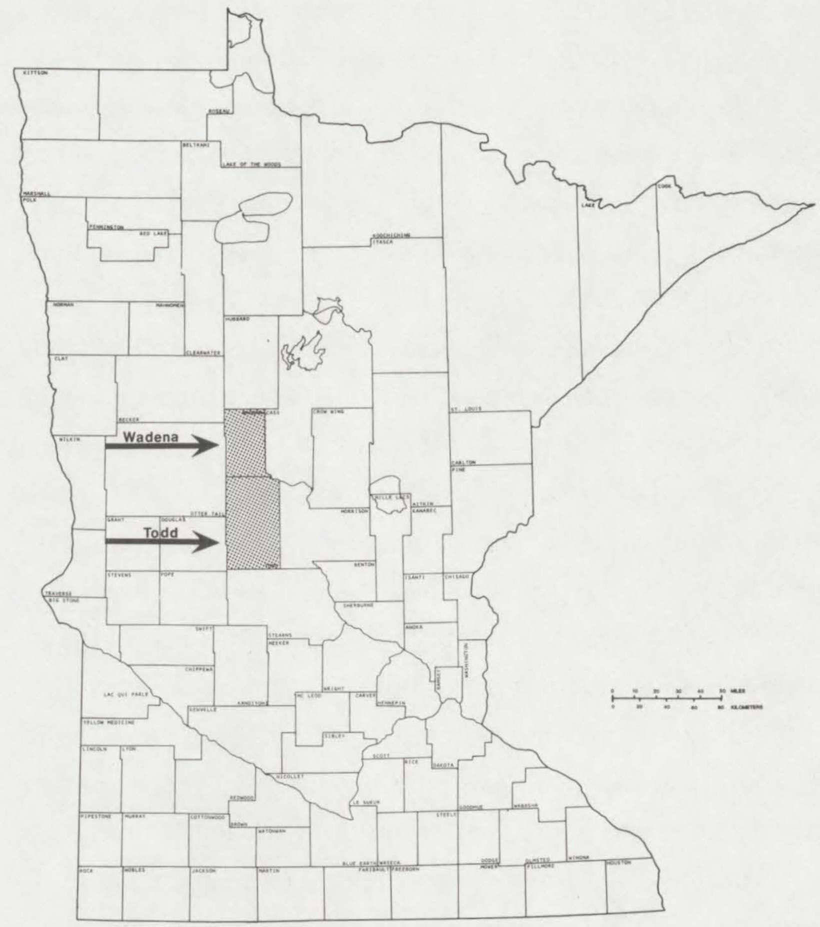
3. TODD AND WADENA COUNTIES

Todd and Wadena counties were chosen as a unit for this second case study (see Figure 24). The wetland distribution and land use pattern of these counties is significantly different from Aitkin County. The important differences include:

1. The principal land use in this two-county study area is agriculture rather than forest.
2. The individual wetland areas within the study area are small in comparison to Aitkin's large contiguous wetland areas.
3. The transportation and riverway systems within this area are more extensive than those of Aitkin County.

Methods of analysis used in Todd and Wadena counties are identical to those used in Aitkin County. A wetland base map was prepared and the capabilities of MLMIS were used to compare various constraints that might affect how much of the wetland base would be available for energy crops. Finally, a composite analysis was prepared for four possible development models.

Figure 24. PILOT STUDY AREA: TODD AND WADENA COUNTIES



THE STUDY AREA

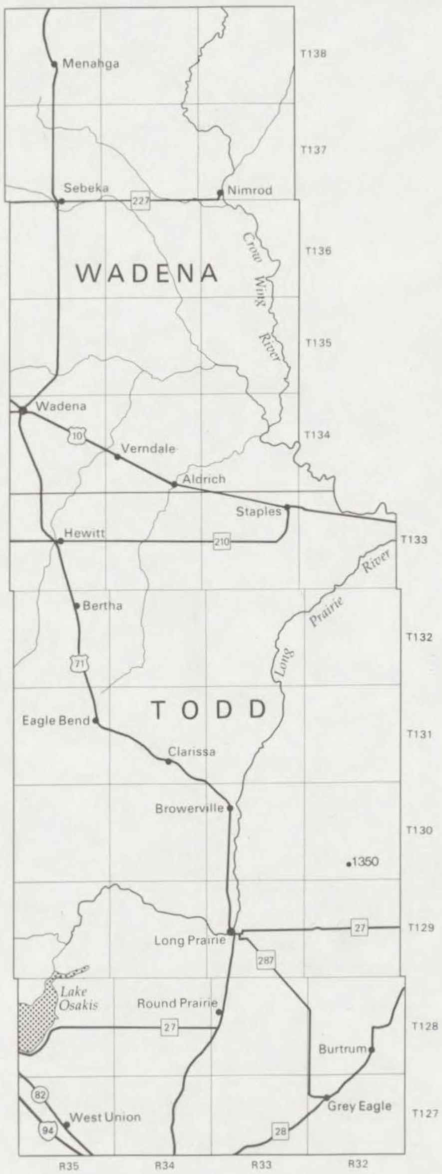
Drumlins and outwash plains are the principal glacial features forming the landscapes of Todd and Wadena counties. The drumlins (cigar-shaped hills of glacial drift deposits) run north-south and are separated by long, narrow deposits of wet mineral soils. The outwash plain covers much of the center of the study area. The well-drained sands and loams that developed on this outwash are now used for farming and forestry. Significant peat deposits also occur in the low-lying parts of the outwash plain.

Several lakes and rivers are located in the study area. The principal river, the Crow Wing, flows through both counties (Figure 25). It enters Wadena County from the north and flows southward through Todd County. Other rivers, including the Long Prairie, are all tributaries of the Crow Wing. Most of the lakes are concentrated in Todd County including Lake Osakis, which has significant recreational value.

The two counties encompass 975,000 acres: 627,000 in Todd and 348,000 in Wadena County. Agriculture dominates more than 50 percent of the land, producing small grains and forage crops. Forests occupy another 30 percent, with significant stands in the Huntersville and Lyons State Forests. A wide variety of tree types are found including deciduous trees on the heavier loam soils in Todd County and red and jack pine on the sandy soils in Wadena County.

The 1980 population for the area was just over 39,000 (25,000 in Todd and 14,000 in Wadena)--a 13 percent increase since 1970. Long Prairie is the major town and county seat in Todd County, Wadena is the county seat in Wadena County.

Figure 25. MAJOR PHYSICAL AND CULTURAL FEATURES OF TODD AND WADENA COUNTIES



THE WETLAND BASE

A composite of wetland soil types and current land use determine the wetland base. The soil types examined were peats and wet mineral soils. Peats occupy approximately 106,000 acres and are found throughout the two counties. The 200,000 acres of wet mineral soils occur primarily in Todd County in depressional landscapes of the interdrumlin region. Only sporadic deposits of these soils are found in the northern sector of the study area.

Current land use was considered so as to exclude wetlands being used for farming or other improved uses. This removed 59 percent of the wetlands in Todd and Wadena counties. The resulting wetland base (see Figure 26) contains 77,400 acres of peatland (37,000 forested and 40,400 open pasture or marsh) and 101,900 acres of wet mineral soils (44,600 forested and 57,300 open pasture or marsh). Most of the peats are located in Wadena County while most of the wet mineral soils are found in Todd County. The total wetland base for the two counties is 179,300 acres.

Figure 26. BASE MAP OF WETLANDS AVAILABLE FOR ENERGY CROPS IN TODD AND WADENA COUNTIES (land use and drainage constraints applied)

LAND USE CONFLICTS

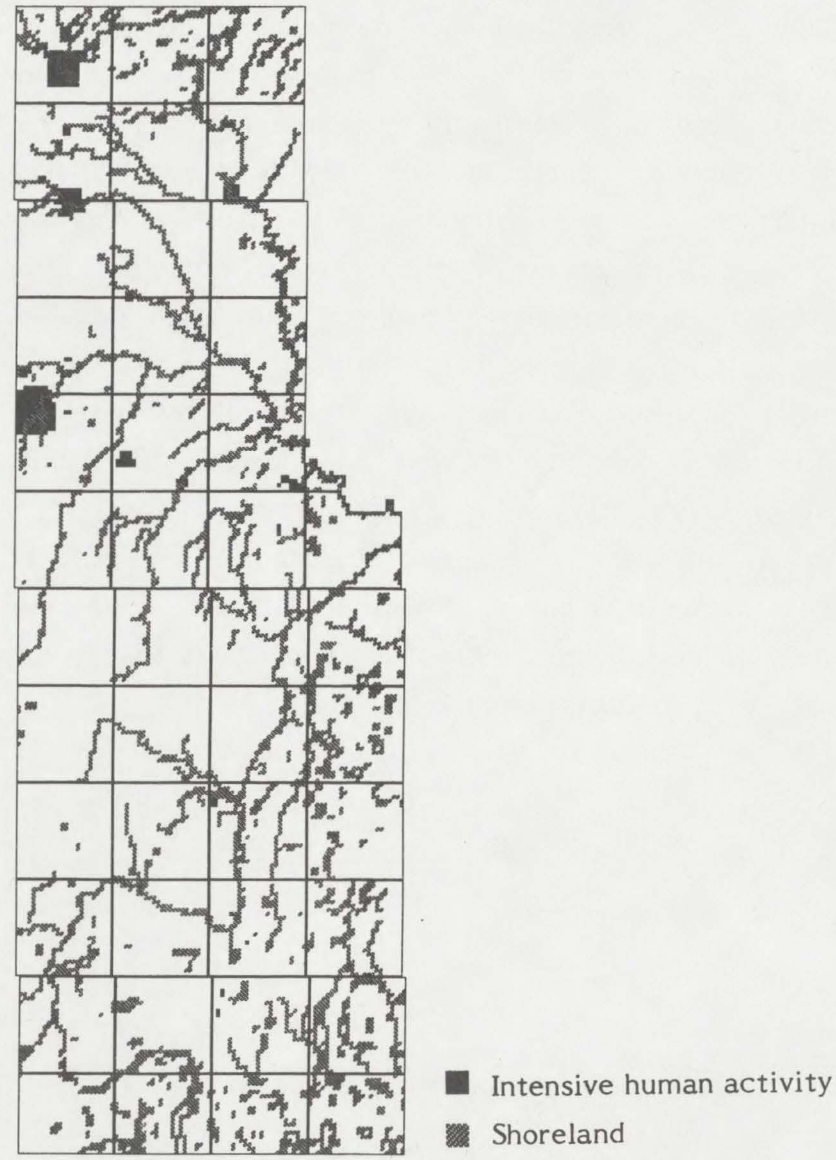
The first of the constraints to be considered are the land use conflicts. As in the Aitkin County study, a map is presented for each constraint to show which of the two county lands are affected by the constraint. Figures are then given in the text to show how these county lands interface with the wetland base. Other existing or potential uses for the land may create a conflict with plans to develop energy crops. Eight such possible conflicts are examined here. In addition to these, two other land use conflicts, potential mineral reserves and commercial peat mining, were considered in the Aitkin County study. No mineral potential is known to exist in the Todd-Wadena area so that constraint has no impact. Peat mining is a potential conflict, but not in the long term because biomass production could be a subsequent use. Both conflicts are ignored in this study.

Human Settlement

Counties direct settlement through zoning. Because the concept of energy crops is new and therefore not specifically addressed in the zoning ordinances, it is unclear where wetland development may be permitted. Undoubtedly, the nature and scale of new bioenergy development will influence county decision making. The broad categories of zoning in Todd and Wadena counties include "intensive human activity" (such uses as commercial, residential, industrial and recreational) and "shoreland zoning" (Figure 27). Shoreland zoning is directed by the state and would also appear to restrict bioenergy development. Other zoning categories, however, such as agriculture, rivers and lakes, flood plains, and unzoned areas may permit bioenergy development.

If no energy crops were allowed in areas already zoned for intensive human activity and shoreland, 19 percent of the wetland base or 33,800 acres would be unavailable--900 because of intensive human activity and 32,900 because of shoreland zoning.

Figure 27. HUMAN SETTLEMENT: LAND AFFECTED BY ZONING RESTRICTIONS



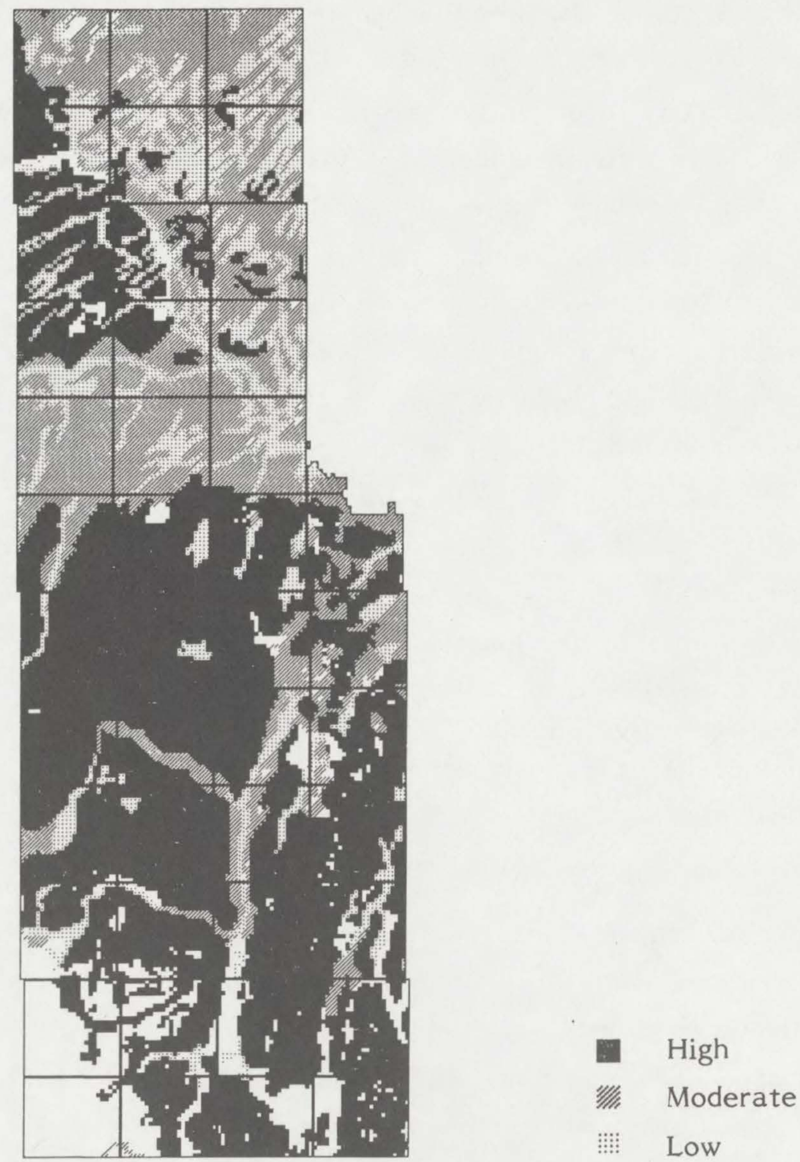
Commercial Forestry

Approximately one-third of the two county area is forested but tree cover falls on a significantly larger proportion of the wetland base (40 percent). The value of trees cut from state and county land in 1981 was $121,339 with 99 percent of the harvest occurring in Wadena County. It is important, therefore, to determine whether the land is more valuable in the long run for growing energy crops or trees. The value of land for commercial forests is influenced by tree type, density, accessibility, distance to market, and soil productivity.

The Department of Natural Resources' ratings of soil productivity were again used. All of the peats in the wetland base have a low rating and all of the wet mineral soils have a high rating.

Figure 28 shows the forest productivity for all of the lands in the two counties. If soils rated as most productive for forestry were not available for bioenergy development, 57 percent of the wetland base would be lost or 101,900 acres--the entire area of wet mineral soils in the wetland base.

Figure 28. COMMERCIAL FORESTRY: SOIL PRODUCTIVITY FOR TIMBER GROWTH



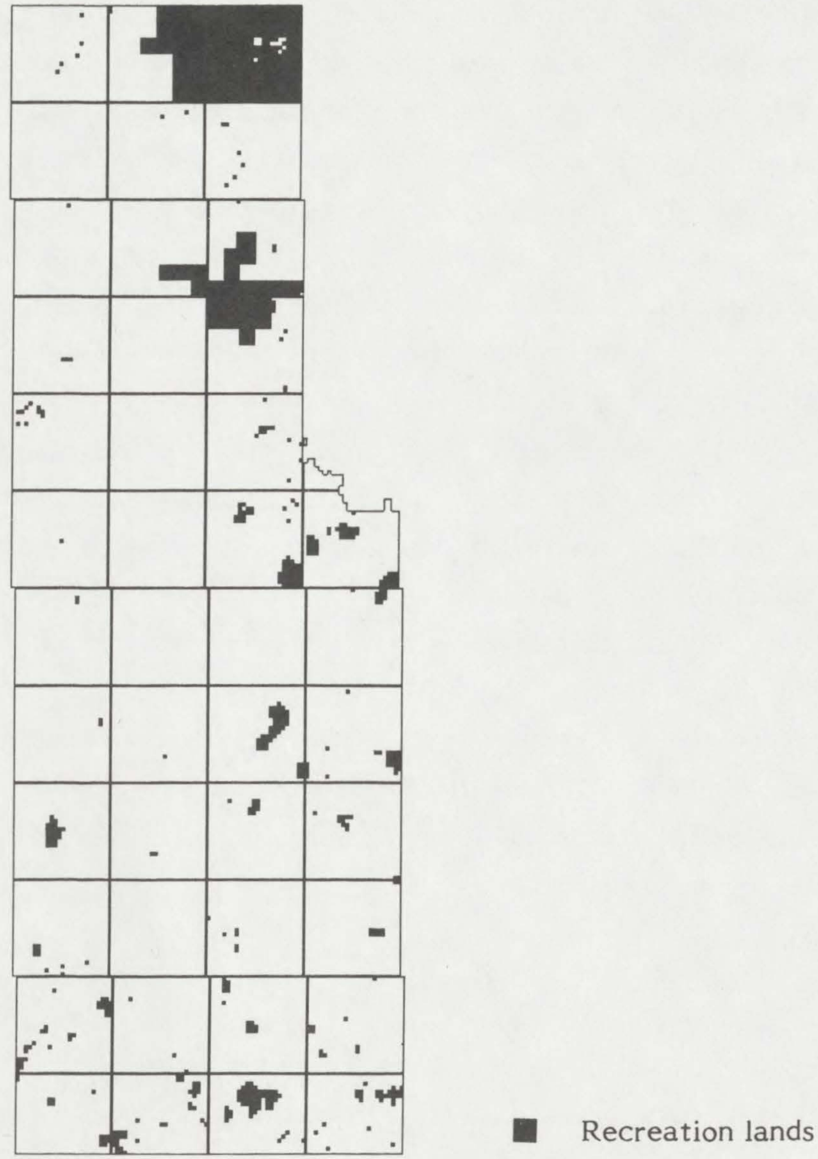
Expansion Agriculture

The potential for the expansion of agriculture is difficult to assess. The number of cultivated acres in an area varies depending upon economic conditions and government commodity programs. The Census of Agriculture, for instance, shows that the cropland acreage in the study area varied by 17,000 acres from 1969 to 1978. It can be assumed that if all other factors were equal (for example, distance to fields, accessibility, soil quality, ability to buy or lease land, and entrepreneurship) farmers would prefer to till fields that are close to their present operation rather than farther away. Of course, in the real world other factors are never equal. This makes it difficult to accurately predict where agriculture may expand. Until additional research is done, no reasonable map predicting the location of agricultural expansion can be drawn. We do not attempt it here.

Outdoor Recreation

The State Comprehensive Outdoor Recreation Plan records the location of public and private recreation facilities. Over 69,000 acres of recreation land are found in Todd and Wadena counties (see Figure 29). If those lands that conflict with the wetland base are excluded, 18,500 acres or 10 percent of the wetland base would be lost--13,600 acres of peatland and 4,900 acres of wet mineral soils.

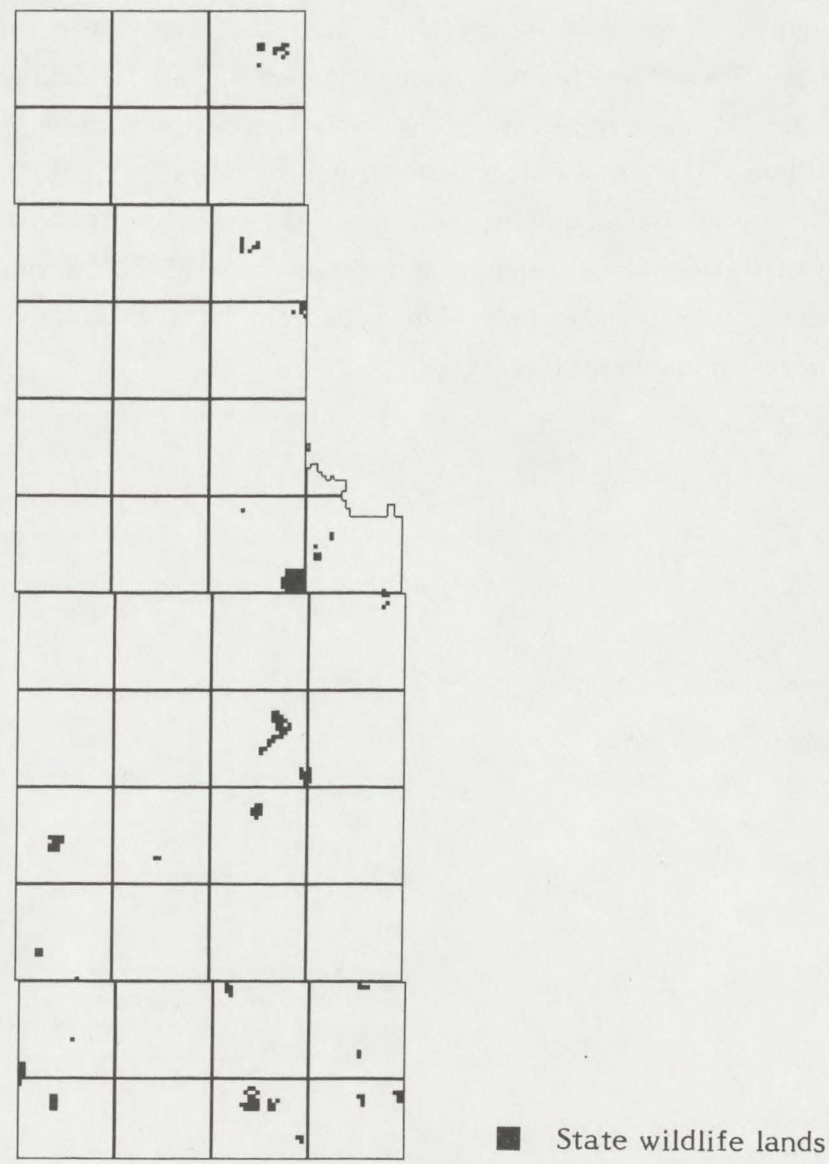
Figure 29. OUTDOOR RECREATION: LANDS CONTAINING PUBLIC AND PRIVATE RECREATIONAL FACILITIES



Wildlife

There are 8,400 acres of state-owned wildlife land in the two counties (see Figure 30). The federal government owns no wildlife land here and privately owned wildlife lands were not considered in this analysis. About 2 percent of the wetland base or 3,200 acres would be lost for energy development if wildlife lands that conflict with the wetland base are excluded--2,400 acres of peat and 800 acres of wet mineral soils.

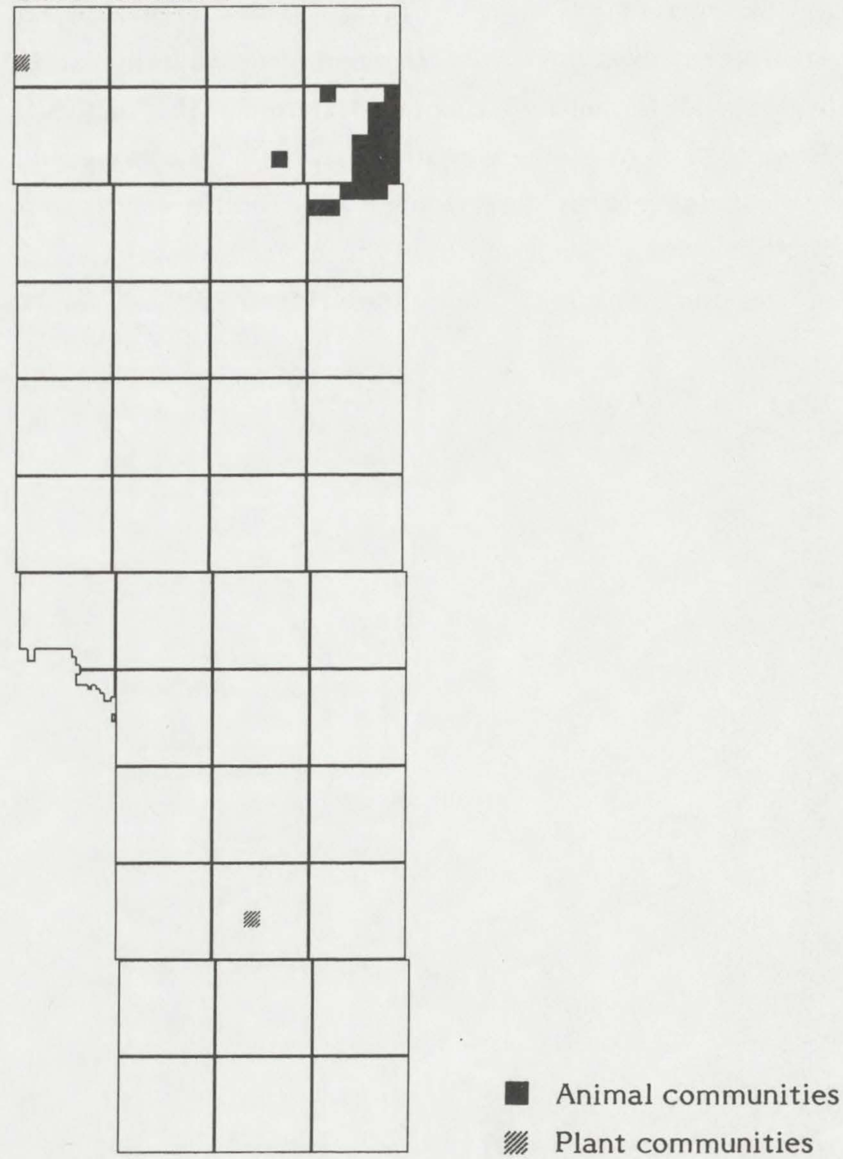
Figure 30. WILDLIFE: LANDS MANAGED OR RECOMMENDED FOR WILDLIFE



Unique Natural Areas

The Minnesota Natural Heritage Program has identified six sites in the study area that are known to have important plant communities or colonial nesting sites of shore birds including gulls, herons, and grebes (Figure 31). These sites do not seem to threaten wetland bioenergy development; only one 640 acre section of wetland contains a unique natural area. The 600 acres affected represent less than 1 percent of the wetland base--all on wet mineral soil.

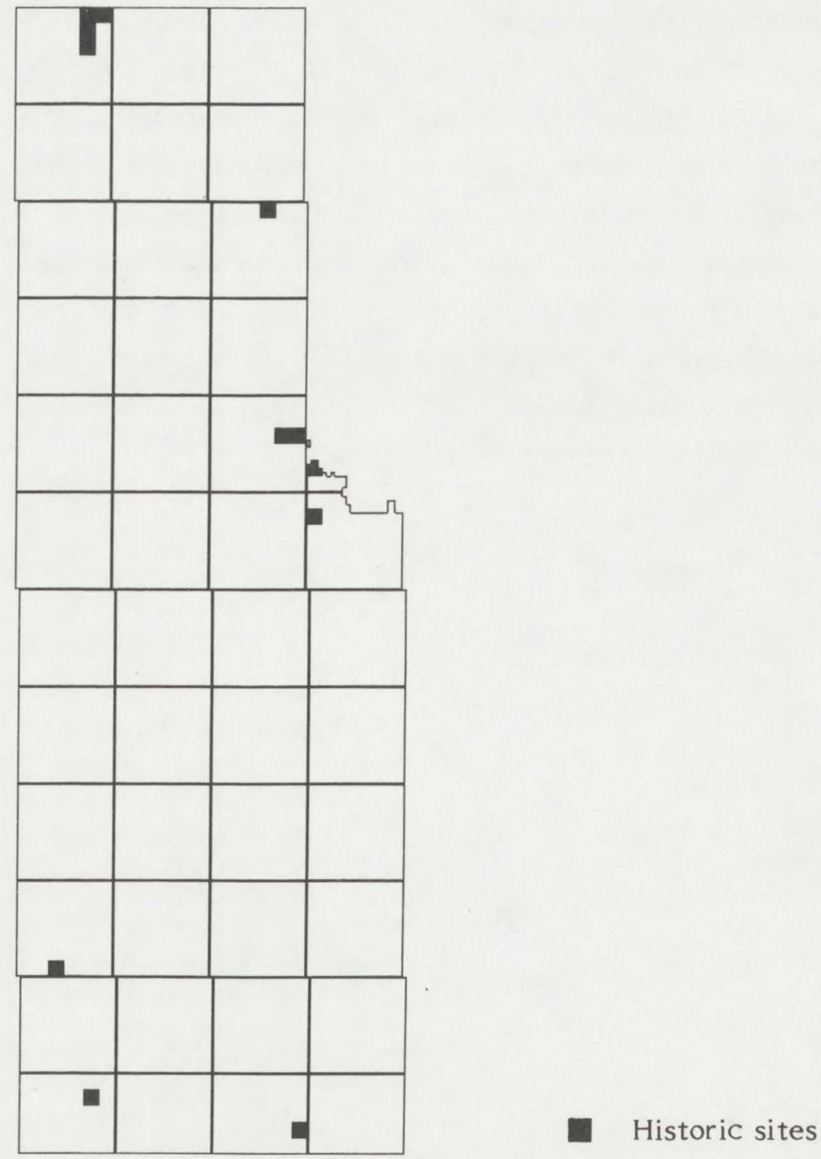
Figure 31. UNIQUE NATURAL AREAS: LANDS CONTAINING UNIQUE PLANT AND ANIMAL COMMUNITIES



Historic Sites

Eight sites containing Indian mounds or artifacts have been identified by the Minnesota Historical Society and are shown on the accompanying map (Figure 32). While most of these mounds are found on small acreages, section data was used to protect against public disclosure. Less than 1 percent of the wetland base is within the area covered by these sections. The 500 acres affected include 200 acres of peat and 300 acres of wet mineral soils.

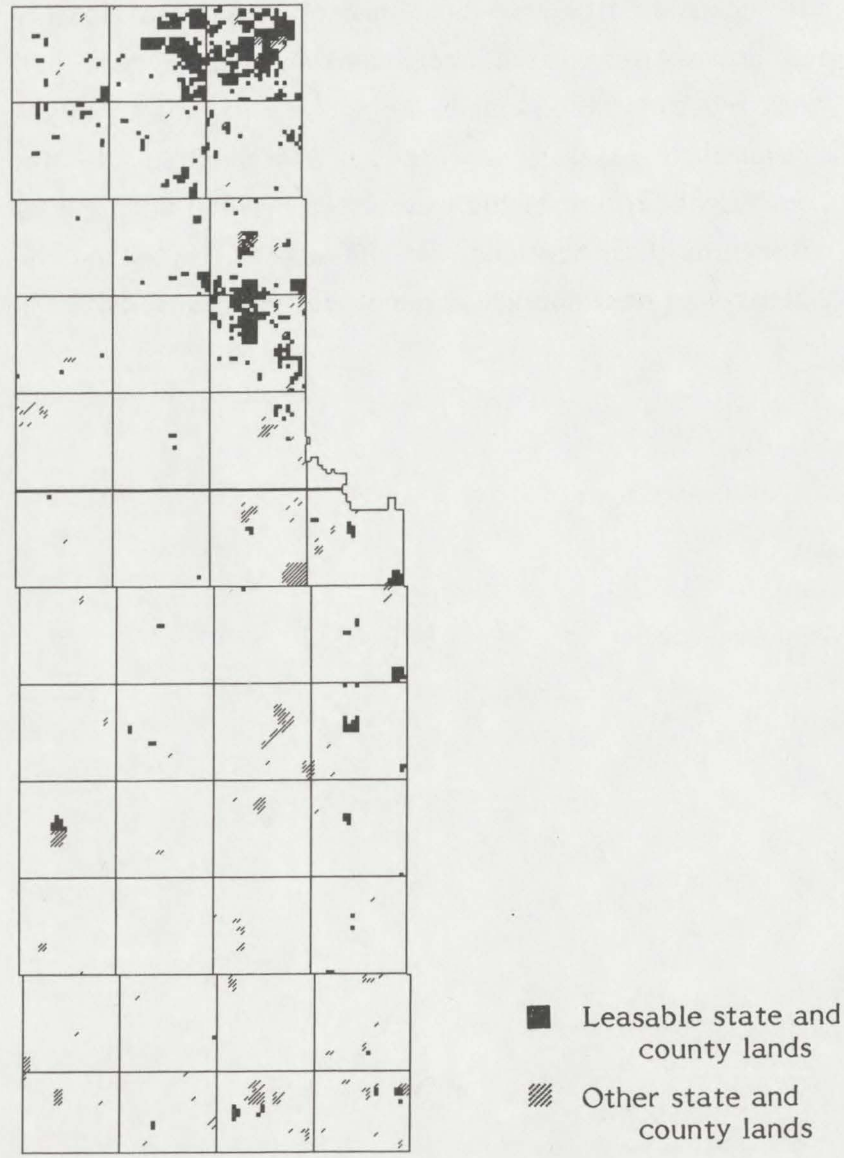
Figure 32. HISTORIC SITES: LANDS CONTAINING PREHISTORIC INDIAN BURIAL GROUNDS



Land Ownership

The ownership pattern of wetlands could be a major constraint on bioenergy development. Wetlands can only be developed with the permission of the owner. Of the various public and private owners, the intentions of only state and county owners are known. From the Department of Natural Resources' Peat Project, certain state and county lands have been identified as not available for lease. If these were excluded from development, 3,700 acres or 2 percent of the wetland base would be lost (Figure 33). Of these acres, 2,700 are peat and 1,000 are wet mineral soils.

Figure 33. LAND OWNERSHIP: STATE AND COUNTY-OWNED LANDS THAT ARE POTENTIALLY LEASABLE



ECONOMIC LIMITATIONS

Five economic constraints were explored for Todd and Wadena counties--the same constraints treated earlier for Aitkin County.

Productivity

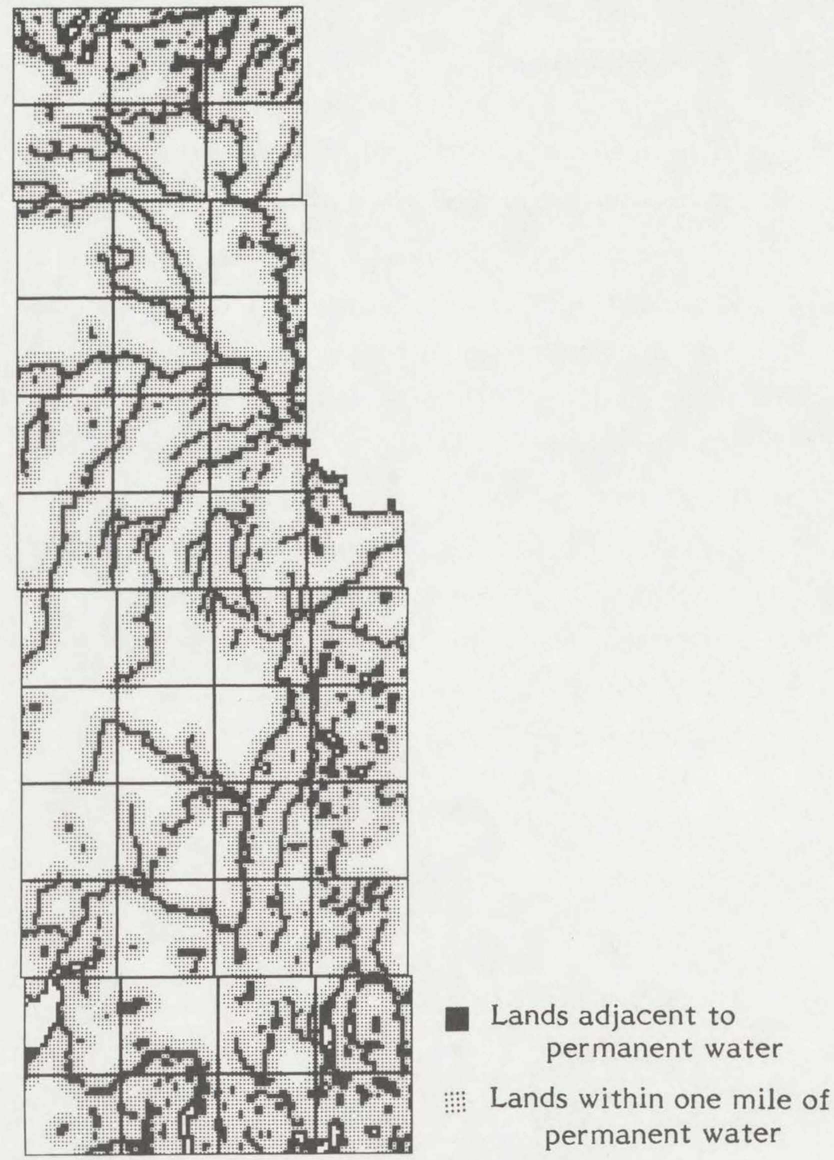
Eighty percent of the wetlands in Todd and Wadena counties are of moderate productivity (143,900 acres). This is divided almost evenly between peat and wet mineral soils. There are virtually no high productivity lands and almost all of the low productivity wetlands (35,200 acres) are wet mineral soils. If low productivity soils are excluded from the wetland base, 20 percent of the base will be lost. The map of wetland productivity (Figure 34) shows that low productivity wetlands are usually not intermixed with the medium productivity soils. The contiguity of the moderately productive wetlands lends itself to efficient management units.

Figure 34. PRODUCTIVITY: PROJECTED SOIL YIELDS FOR HERBACEOUS PLANTS

Water Access

In Todd and Wadena counties about half of the wetlands are within one mile of a stream, river, or lake. Their distribution is shown in Figure 35. If wetlands farther than one mile from permanent waterways are excluded, 87,000 acres of wetlands (39,000 peats and 48,000 wet mineral soils) are lost from the wetland base. This represents 49 percent of the base. Since the state of Minnesota regulates water use from public lakes and rivers, proximity to them does not necessarily mean that use of the water will be assured.

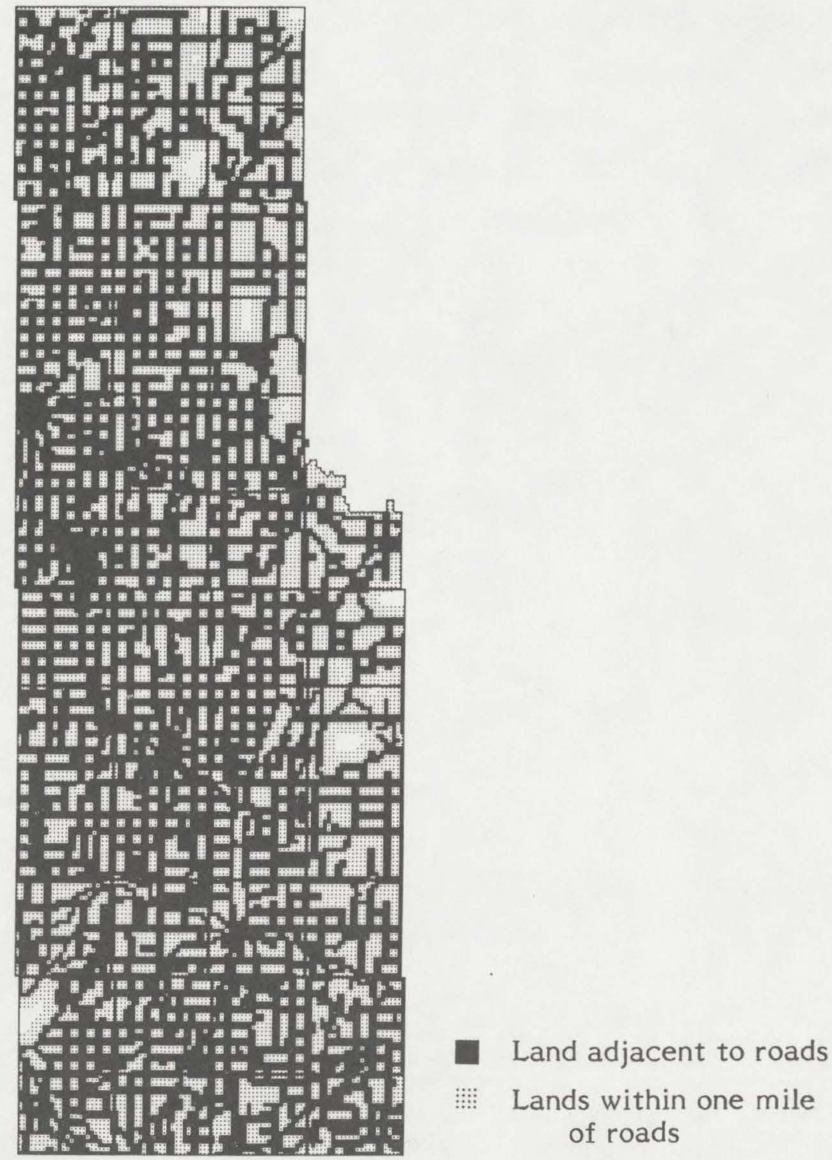
Figure 35. WATER ACCESS: PROXIMITY TO PERMANENT LAKES, RIVERS, AND STREAMS



Road Access

Lack of road access should not be a hindrance to resource development in Todd and Wadena counties. Ninety-nine percent of the wetlands are within one mile of a highway or road (see Figure 36). Only 1,900 need be excluded from the wetland base--1,800 acres of peat and 100 acres of wet mineral soil.

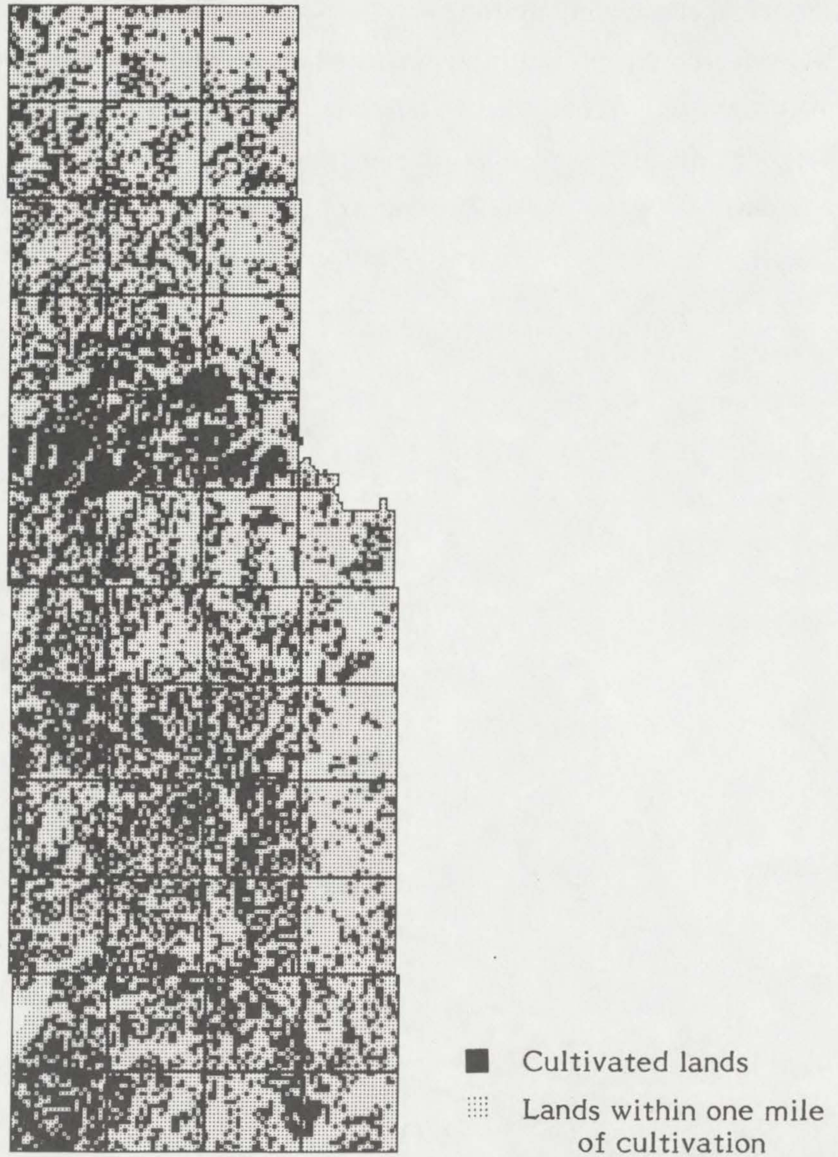
Figure 36. ROAD ACCESS: PROXIMITY TO PUBLIC ROADS



Access to Agriculture

All wetlands in the study area are within one mile of cultivated land (see Figure 37).

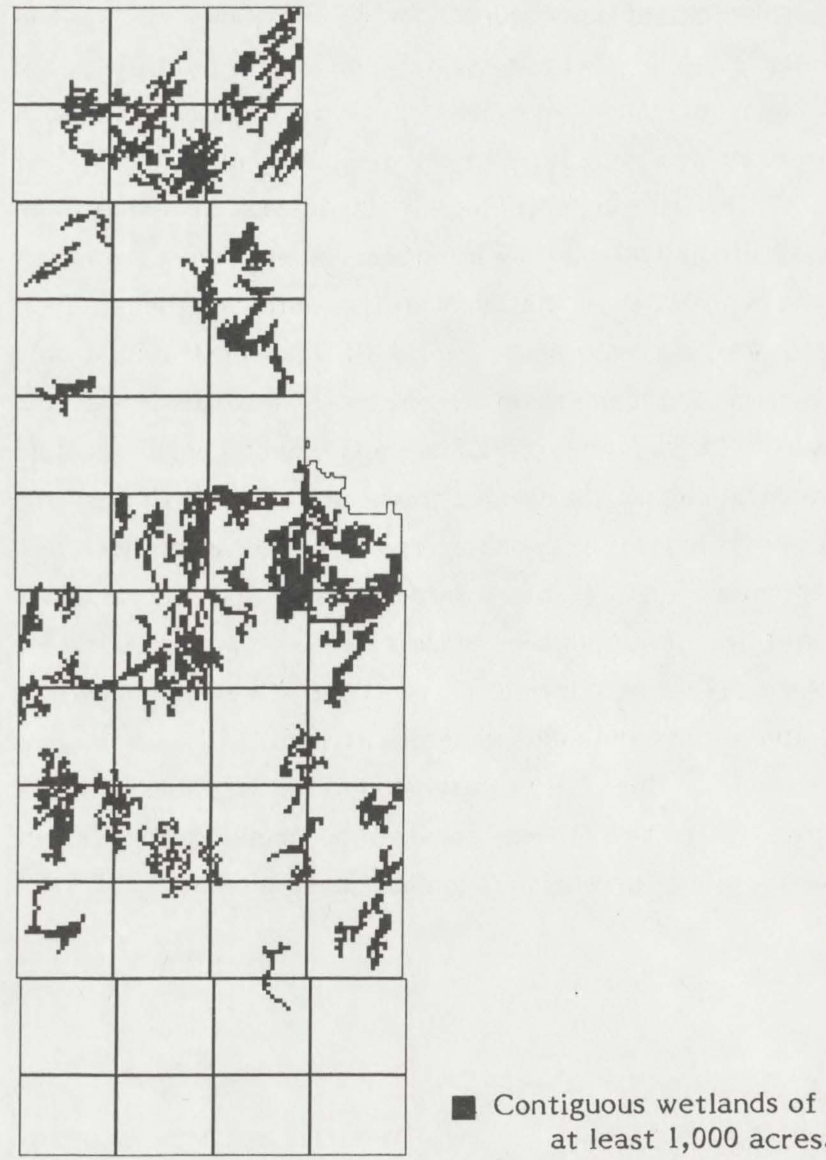
Figure 37. ACCESS TO AGRICULTURE: PROXIMITY TO CULTIVATED LANDS



Management Unit Size

The pattern and distribution of wetlands varies significantly across the state. The wetlands in Todd and Wadena counties do not show the broad contiguous expanses we found in Aitkin County. The actual distribution for these two counties of wetland areas large enough to constitute a management unit is shown in Figure 38. For this analysis a minimum of 1,000 acres is used to define a wetland management unit. Seventy percent of the 179,300 wetland acres meet this requirement. Only 54,400 acres of wetland would be excluded if areas not fitting into a management unit size were excluded--24,600 acres of peats and 29,800 acres of wet mineral soils.

Figure 38. WETLAND MANAGEMENT UNITS



SUMMARY OF CONSTRAINTS

As in the report on Aitkin County, it seems useful to summarize the constraints studied in Todd and Wadena counties and their potential impact on limiting the amount of land available for energy crops. Table 6 presents a capsule form of the Todd-Wadena analysis.

Though the percentage of land areas in the wetland base are not as high as in Aitkin County, the constraints on the use of these wetlands are generally smaller in Todd and Wadena counties. Over half the constraints would restrict development on 10 percent or less of the wetland base. County zoning (human settlement conflict) would constrain about the same percentage of land (19 percent) as in Aitkin and is probably open to negotiation here too. Unfortunately, the other large constraints may be more limiting (i.e., commercial forestry and productivity) or place severe restrictions on the type of development (i.e. water access and management unit size).

As in the Aitkin case study, the next section will investigate how these constraints combine to restrict various kinds of wetland biomass development.

Table 6. POSSIBLE CONSTRAINTS ON USE OF WETLAND BASE IN TODD AND WADENA COUNTIES

Constraint	Acreage Affected			Percent
	Peatlands*	Wet Mineral Soils**	Total***	
LAND USE CONFLICTS				
Human settlement	18,900	14,900	33,800	19
Commercial forestry	--	101,900	101,900	57
Expansion agriculture			?	?
Outdoor recreation	13,600	4,900	18,500	10
Wildlife	2,400	800	3,200	2
Unique natural areas	--	600	600	1
Historic sites	200	300	500	1
Land ownership	2,700	1,000	3,700	2
ECONOMIC LIMITATIONS				
Productivity	200	35,000	35,200	20
Water access	39,000	48,000	87,000	49
Road access	1,800	100	1,900	1
Access to agriculture	0	0	0	0
Management unit size	24,600	29,800	54,400	30

*77,400 acres in total

**01,900 acres in total

***179,300 acres

WETLAND DEVELOPMENT STRATEGY

Four possible development strategies were assessed for Todd and Wadena counties. As with Aitkin County, the no constraints and maximum constraints models were included as a way of establishing minimum and maximum models of how much land might be available. The farm development model and the commercial development model are more likely to be useful strategies for developing energy crops in Minnesota. The constraints applied for each of these models are shown in Table 7. Continued analysis of these development models here includes consideration of the effects of the sequential order in which the constraints are applied.

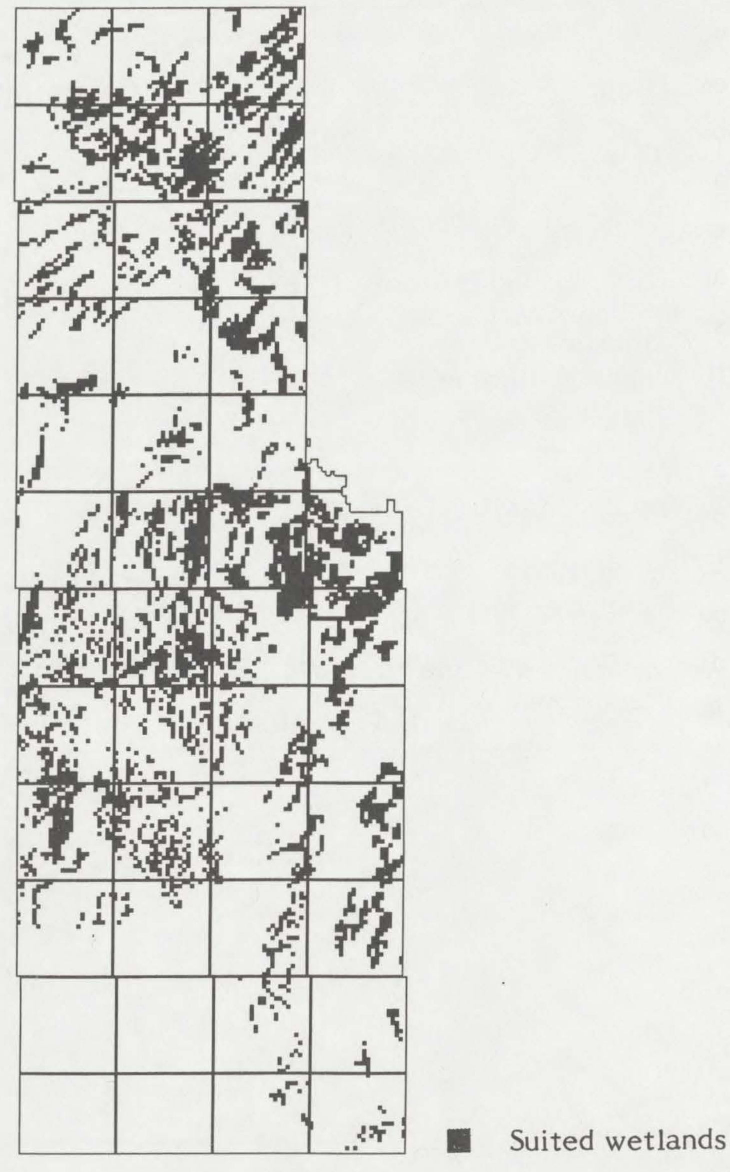
Table 7. CONSTRAINTS APPLIED IN WETLAND DEVELOPMENT STRATEGIES FOR TODD AND WADENA COUNTIES

	MODEL			
Constraints	No Constraints	Maximum Constraints	Farm Development	Commercial Development
LAND USE CONFLICTS				
Human settlement		●		●
Commercial forestry				
Expansion agriculture				
Outdoor recreation		●	●	●
Wildlife		●	●	●
Unique natural areas		●	●	●
Historic sites		●		●
Ownership restrictions		●	●	●
ECONOMIC LIMITATIONS				
Productivity		●	●	●
Water access		●		●
Road access		●	●	
Access to agriculture		●	●	
Management unit size		●		●

No Constraints Model

In this strategy it is assumed that no economic limitations or land use conflicts will reduce the acreage available for energy crop development. The maximum amount of land available is thus displayed in Figure 39. The map is the same as that for the wetland base in Todd and Wadena counties: 179,300 acres of wetland are available with 43 percent (77,400 acres) in peats and 57 percent (101,900 acres) in wet mineral soils.

Figure 39. NO CONSTRAINTS MODEL: MAXIMUM AVAILABLE WETLANDS FOR ENERGY DEVELOPMENT

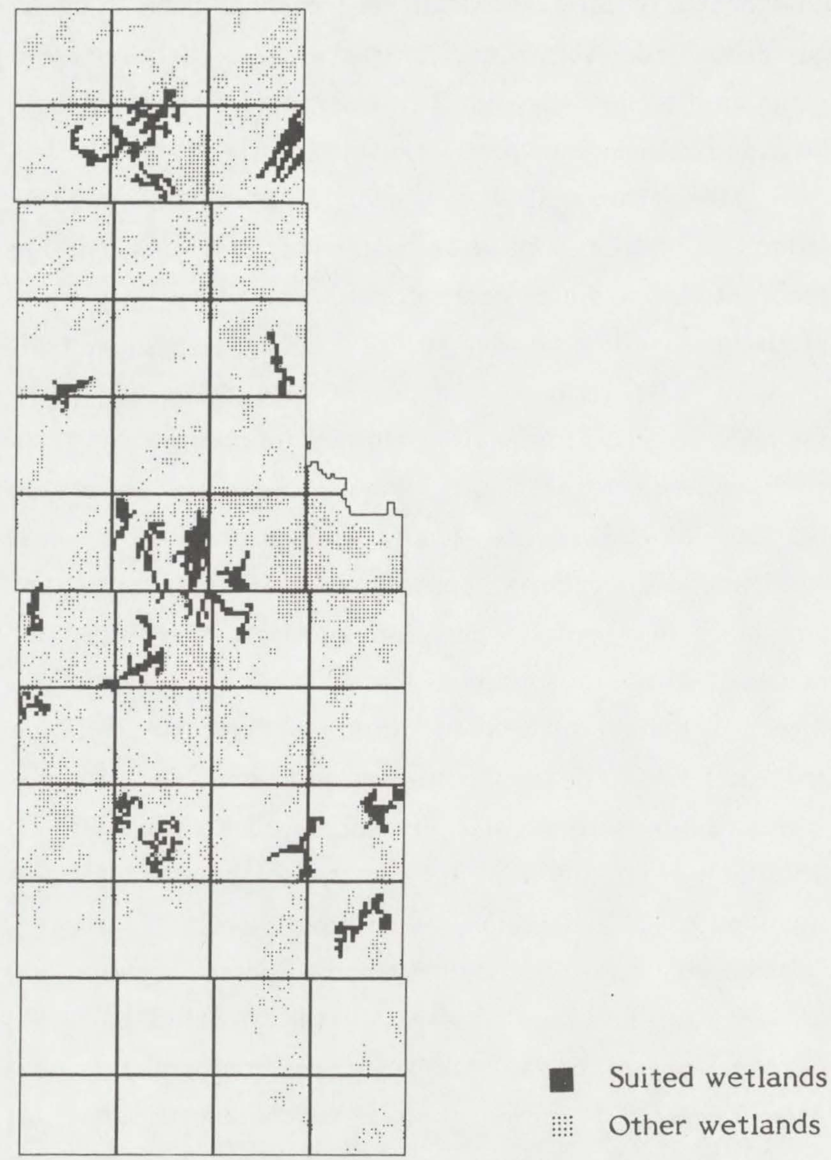


Maximum Constraints Model

Here the strategy is to assume that all restraints will apply. Only two restraints (commercial forestry and expansion agriculture) are omitted--commercial forestry because no conflict need exist since energy crops could be a subsequent land use after trees were cleared and sold--expansion agriculture because the effects of this conflict are too difficult to assess without considerably more study. These two constraints are not applied for any of the models studied here.

This model shows the minimum amount of land available for energy crops in the two counties. In total, 34,700 acres of wetland (19 percent) would be available: 15,700 acres of peat and 19,000 acres of wet mineral soils. Figure 40 shows how these available wetlands are distributed. This compares with 3 percent available in Aitkin County.

Figure 40. MAXIMUM CONSTRAINTS MODEL: MINIMUM AVAILABLE WETLANDS FOR ENERGY DEVELOPMENT



Farm Development Model

This strategy assumes that farmers could improve adjacent or nearby wetlands for growing crops such as cattails. Under some conditions, the same equipment and skills used for growing small grains and forage crops could be used for bioenergy production.

The most desirable wetlands, according to this model, are those lying near cultivated lands and existing road networks. Water needs could be met through the use of shallow wells or drainage ditches. Large management units of 1,000 acres or more are not necessary since farmers would be integrating the new bioenergy crops into their existing operation. Lands identified as unique natural areas, wildlife lands, and outdoor recreation facilities are potential constraints. Historic sites are avoidable in a small operation and are, therefore, not considered an obstacle. County zoning ordinances, directing human settlement, do not present a hinderance to small scale development. Conditional permits for water appropriation and discharge could probably be obtained; especially where a limited number of acres are involved. Ownership restrictions were, however, considered a conflict and applied as a constraint here.

In total, 128,600 acres of the wetland base (72 percent) would be available for development by local farmers: 62,300 acres of peat and 66,300 acres of wet mineral soils. Figure 41 shows their distribution. This compares with 36 percent available in Aitkin County.

Figure 41. FARM DEVELOPMENT MODEL: WETLANDS SUITED FOR SMALL SCALE ENERGY DEVELOPMENT

Commercial Development Model

This model allows us to examine large scale development as a possible strategy in Todd and Wadena counties. The constraints to be applied included six land use conflicts and three economic limitations.

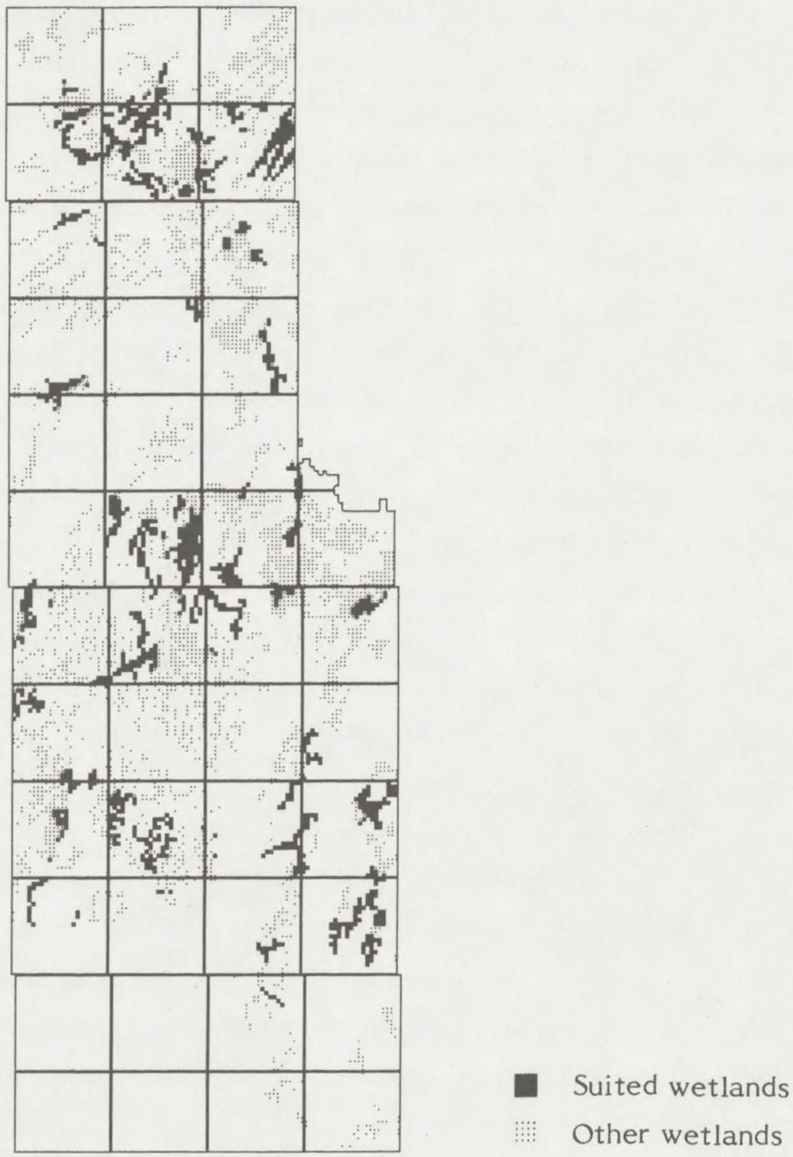
An assumption of this model is that large scale development may have a detrimental effect on wetlands that contain unique natural areas, historic sites, wildlife refuges, or recreational facilities. Areas containing these land use conflicts are excluded from consideration, therefore, as sites for energy crops. The urban zoning districts are also excluded because a large scale commercial operation could pose as a significant conflict to existing or future settlement patterns. Shoreland districts are excluded. Only leasable lands in public ownership and private lands are considered as available for this kind of development. As in the other models, the constraints concerning forest productivity and expansion agriculture were not applied.

Among the economic factors, this model selects for tracts of high and moderately productive wetlands. Proximity to permanent waterways is important because it may be necessary to flood and drain the wetland areas. Finally, the minimum management unit size was considered. This size was set at 1,000 acres rather than the 4,000 acres minimum used for Aitkin County.*

By applying all nine constraints, we found that 34,700 acres of the wetland base would be available for energy crops. This represents 19 percent of the wetland base--15,700 acres of peats and 19,000 acres of wet mineral soils. Figure 42 shows the distribution of the available wetlands, located in eighteen district sites spread across the two county area. This compares with 9 percent available in Aitkin County.

*For purposes of comparison, computations of the wetland acreage available using the 1,000 acre limit have been inserted in footnotes in the Aitkin County section.

Figure 42. COMMERCIAL DEVELOPMENT MODEL: WETLANDS SUITED FOR LARGE SCALE ENERGY DEVELOPMENT



DISCUSSION

The four analysis models allow us to explore which parts of the wetlands are potentially suited for bioenergy development. The first two models, relatively simple, establish maximum and minimum land use constraints. The farm and commercial models demonstrate realistic ways in which the wetland acres might be developed. All of the acreage available for the commercial model also fulfills the requirements of the farm development model since access to roads and access to agriculture are not significant limitations for a commercial model and are, at any rate, readily available throughout Todd and Wadena counties. The 128,600 acres available under the farming model, then, also represent the total number of wetlands that are suited for all types of wetland bioenergy development in the study area (34,700 of them are suitable for commercial development as well as farming development).

The maximum constraint and commercial development models turn out to be identical. The only distinction between these two is the additional constraints of road access and access to agriculture which are applied to the maximum constraint model but not to the commercial model. Given the other constraints applied, neither of these factors have an impact on the final lands available hence, these models produce identical results.

Who owns the unconstrained wetlands could be an important determinant of development timing and strategy. Development of public lands will require public policy decisions, whereas privately owned lands require only private entrepreneurs. These two case studies are dramatically different in their ownership patterns. In Aitkin County, public leasable lands represent half or more of the available wetlands under every development model. Public policy will play a major role in Aitkin County. The same is not true in the Todd-Wadena study area (see Table 8). Most of the wetland is in private ownership and only a small percentage (6 percent) is public and leasable. In the farm model, 2,700 acres of the state/county wetlands are available for lease, representing only 2 percent of the 128,600 acres otherwise available. An equally small percent of public lands is available under the commercial model. If wetland development is going to happen in Todd-Wadena, it is going to have to take place on private land.

Which constraints caused the largest loss of wetlands in each model? Answers to this question indicate the critical factors that must be overcome if wetland biomass development is to become a reality. Many of the constraints coincide with each other so that the simple examination of constraints, one by one, does not necessarily identify the largest single constraint.

In addition, applying the constraints in a different order would have changed the absolute number of acres lost by each constraint. However, the relative magnitude of these losses would probably be the same and the rankings of which are most important are almost certainly right. These sequential impacts are shown in Tables 9 and 10.

For the farm development model (Table 9), relatively little land was constrained from development. Soil productivity was the biggest factor accounting for an initial loss of 20 percent. Outdoor recreation facilities was the only other factor constraining a substantial amount of land. For the commercial development model, Table 10, over 80 percent of the land was constrained. The biggest factor was clearly the 1,000 acre minimum management unit size, accounting for 30 percent of the loss when it was first applied, and an additional 9 percent loss when it was applied the second time, after all other constraints had been applied. Other significant factors were water access and soil productivity.

Table 8. EFFECT OF LAND OWNERSHIP ON WETLANDS AVAILABLE UNDER EACH DEVELOPMENT MODEL IN TODD & WADENA COUNTIES

Model	State and County Leasable Wetlands Available*	Percent of Total	Total Wetlands Available*
Minimum constraint	10,300	6	179,300
Maximum constraint	800	2	34,700
Farm development	2,700	2	128,600
Commercial development	800	2	34,700

*in acres

Table 9. SEQUENTIAL IMPACTS OF CONSTRAINTS APPLIED IN FARM DEVELOPMENT MODEL

Order of Constraints	Incremental Loss of Wetland Acres	Cumulative Total of Remaining Wetlands	Percent of Remaining Wetlands
WETLAND BASE	0	179,300	100
ECONOMIC LIMITATIONS			
Productivity	35,200	144,100	80
Road access	900	143,200	80
Access to agriculture	0	143,200	80
LAND USE CONFLICTS			
Unique natural areas	0	143,200	80
Wildlife	2,600	140,600	78
Outdoor recreation	11,800	128,800	72
Ownership restriction (land not leasable)	200	128,600	72
FINAL	50,700	128,600	72

Table 10. SEQUENTIAL IMPACTS OF CONSTRAINTS APPLIED IN COMMERCIAL DEVELOPMENT MODEL

Order of Constraints	Incremental Loss of Wetland Acres	Cumulative Total of Remaining Wetlands	Percent of Remaining Wetlands
WETLAND BASE	0	179,300	100
ECONOMIC LIMITATIONS			
Management unit size	54,400	124,900	70
Water access	38,900	86,000	48
Productivity	24,500	61,500	34
LAND USE CONFLICTS			
Historic sites	200	61,300	34
Unique natural areas	0	61,300	34
Wildlife	2,200	59,100	33
Outdoor recreation	7,900	51,200	29
Human settlement	300	50,900	28
Ownership restrictions (land not leasable)	100	50,800	28
MANAGEMENT UNIT SIZE*	16,100	34,700	19
FINAL	144,600	34,700	19

*As in the Aitkin study, the management unit size constraint is applied twice. The first application removes the smaller wetland areas. The second application is required to eliminate fragments of original areas resulting from application of intermediate constraints.

CONCLUSIONS

Bioenergy has the potential for becoming economically important in Todd and Wadena counties. Nearly 180,000 acres of undeveloped wetlands are located there and most of these could be improved for bioenergy applications. The existing cultivated acreage of farms in these two counties would be increased by 32 percent if the 128,600 acres noted in our farm development model were put into production. The 34,700 acres produced through the commercial model are found in eighteen scattered sites, each containing at least 1,000 acres of contiguous suitable wetlands. These large individual areas could satisfy a number of new commercial operations. Surprisingly, 98 percent of the wetlands generated through either the farm or commercial model are privately held.

Thirteen separate constraints were addressed in the modeling process. Only three, however, were responsible for significantly reducing the acres of available wetland. These were soil productivity, water access and management unit size. Soil productivity was the important constraint for the farm development model, reducing the wetland base from its initial figure of 179,300 acres to 144,100 acres; a change of 20 percent. All other constraints combined reduced the available acreage by only 8 more percentage points. In the commercial model, all three constraints played important roles in reducing the number of wetland acres. The management unit size, water access, and soil productivity, applied in that sequence, removed more than 117,000 acres or 66 percent of the wetlands from being available. Together, all subsequent constraints reduced the acreage figure by less than 27,000 acres, an additional 15 percent.

In order to increase the number of wetland acres available through both models, bioenergy developers would need to overcome these constraints. For example, improving the fertility of naturally poor soils would increase the number of acres of available wetland for both models. If commercial operators could grow woody crops, such as alders and willows, in those wetlands not having water access, the acreage available for production would greatly increase. Finally, if commercial operators could economically farm wetlands found in concentrations of less than 1,000 acres, the opportunities for commercial ventures would improve significantly.

4. WHAT THE CASE STUDIES SUGGEST

Bioenergy is new in Minnesota and, understandably, many important questions have no easy answers. For this reason, our research addressed a wide range of potential economic and land use limitations which may control the availability of wetlands for energy development. Our approach was by no means absolute. As demonstrated here, the acreage and distribution of "suitable wetlands" can change dramatically through the alteration of a single constraint. Therefore, a principal achievement of this investigation is not a final map or acreage figure but rather a technique by which Minnesota's wetlands can be systematically inventoried and studied. It is hoped that this approach can serve as a model for continued research.

Aitkin County was the first study area where our approach to the land use problems was applied. A primary purpose in studying a second area was to observe the effect of the same wetland suitability models on a different region of the state. The impacts of the individual constraints in the two study areas were dramatically different. In Aitkin County, road access and access to agriculture proved to be major constraints. Individually, these two factors reduced the wetland base by 46 and 26 percent respectively. However, for the farm model in the Todd - Wadena study area, these same constraints had little or no impact on the wetland base.

Management unit size in the commercial model was a major constraint for the Todd -Wadena study area. Using a minimum of a 1,000 acres, this constraint alone reduced the wetland base by almost 40 percent. In Aitkin County, a minimum management unit size of 4,000 acres reduced the wetland base by only 8 percent. If the 4,000 acre minimum had been applied in the Todd - Wadena area, nearly 90 percent of the wetland base would have been eliminated.

Land ownership presents a major constraint in determining which wetlands may ultimately be developed. Obviously, only those wetlands where the owner consents can be used in a bioenergy venture. In Aitkin County, the State of Minnesota could play a major role in wetland development. Nearly 41 and 62 percent of the wetlands generated through the farm and commercial models are available by lease from the state. For the Todd -Wadena area, however, less than 2 percent of the wetlands under either of these two models are state leasable. As a result, private entrepreneurs must take the lead for initiating bioenergy operations in these two counties.

Generally, one might expect Aitkin County, rather than the Todd - Wadena area, to have a higher percentage of its wetlands available for any type of bioenergy development. This is because much of Aitkin County is sparsely settled and many land uses that might conflict or compete with bioenergy have not been instituted. This was not the case, however. The Todd - Wadena area had a greater proportion of its wetlands available through the different models than Aitkin County. The existing roads and farms proved to be assets to bioenergy, as addressed here, especially in the farm development model. Table 11 compares the acreage figures of the wetland base and the various development models for the two study areas.

Table 11. WETLAND ACREAGE AVAILABLE IN AITKIN COUNTY AND TODD AND WADENA COUNTIES

	Aitkin County		Todd-Wadena Counties	
Development Model	Acres	Percent	Acres	Percent
Wetland base (no constraints)	568,500	100	179,300	100
Maximum constraint	15,700	3	34,700	20
Farm development	205,000	36	128,600	72
Commercial development	51,300	9	34,700	19

PROJECTIONS FOR THE ENTIRE STATE

Using the figures from Table 11 it is possible to make a rough estimate of the number of acres of wetland available for development in the state of Minnesota. The state's wetland base is approximately 8.8 million acres. Using the fall off rates for the two study areas, maps of land use, ownership, and wetland distribution, and tables of county wetland bases, the authors estimated the available acreage in each county. Summing these figures, the authors estimate 2.7 million acres may be available for farm development. Alternatively, 1.9 million acres may be available for commercial development. Together, nearly 3 million acres may be available for energy crops grown on wetlands.

This study has examined the geographical issues which may ultimately control bioenergy development in Minnesota. Many questions that have no easy answers still remain.

When the Aitkin County models were used in the Todd - Wadena area the results were different and unpredicted. As a result, projections of the availability of Minnesota's wetland resource can only be speculative without first conducting county or regional bioenergy studies. These two case studies, however, have shown that accessibility, economics, land use, land cover, and inherent suitability are essential components of Minnesota's bioenergy research programs. The studies demonstrate that map overlays are an important tool in analyzing the complex interactions of these land use patterns.

RECOMMENDATIONS FOR FUTURE RESEARCH

The feasibility of growing energy crops on Minnesota's wetlands is being explored by many different disciplines. Because each effort is dependent upon the work of another, all programs must move ahead together. The results of this study should prove useful to the botanists, economists, engineers and biochemists who are examining other aspects of bioenergy. In turn, their findings will be used to refine and strengthen the land use research program.

This study has also raised many questions which have no immediate answers. Recommendations for further work are suggested here. The results from such studies will be valuable to all bioenergy research programs.

1. <u>The land use models developed in Aitkin County and Todd and Wadena Counties need to be tested elsewhere</u>. Other parts of Minnesota have different landscapes and may show different results. Looking at different areas will help in creating a better estimate of the

total area of wetlands available for development within Minnesota.

2. Other researchers in the comprehensive University study need to take note of the findings in their future work.

   a. Botanists should seek ways to plant cattails without first draining the land. For large areas drainage is too difficult.

   b. Agricultural engineers should seriously explore ways to harvest the crop without first draining the land for the same reasons.

   c. Biochemists may need to look at converting wetland crops other than cattails if the above difficulties cannot be overcome.

   d. Economists need to oversee all work. Most important now is probably the question of efficient scales of operations given transport costs and efficient conversion plant size.

3. Work must be done on other wetland plants. Woody plants such as aspen, willow, and alder grow well on wetlands and could be harvested in winter without significant loss of biomass. Cattails never have over half their biomass above ground and the proportion decreases after a peak in late summer.

4. The problem of access to water could be addressed in other ways. The use of holding basins with water transferred by efficient pumps might significantly increase the wetland area which could be developed in Aitkin County.

5. The amount and timing of these water needs must be specified. Some lakes and streams may be physically unable to meet these needs. Legal problems may restrict others.

6. The social, economic, and environmental impact of wetland biomass development must be addressed. Can the infrastructure of areas which are likely candidates support the development? What about the impact on water quality and flooding potential. These topics have not yet been addressed.

7. This land use research could be refined in several ways. It was intended as a reconaissance survey and is probably sufficient until more research is done in their areas by other members of the study team. However several improvements and extensions could be made.

a. Topography studies could be used to identify basins as potential water storage areas.

b. Present cover of the wetlands may limit their usefulness, especially for the farm model, unless some efficient removal method and a use for this material can be found. An inventory of the cover of wetlands available in each model could be made.

c. The interaction of variables in each model could be more specifically investigated.

d. A more detailed wetland inventory would provide a better starting point for this research; especially for the farm development model. Small wetlands do not appear in the general Soil Atlas. No such inventory yet exists for Aitkin County.

8. Research and development often go well together. Before much longer, a pilot development should be established to see whether research to date makes sense in the real world.

PUBLIC POLICY ISSUES

If federal, state, and local governments wish to encourage a wetland biomass industry, they will face a number of important policy issues. Some of these issues involve encouraging the industry. Others involve minimizing negative side effects of this development.

1. The counties have control over most local land use decisions through their zoning ordinances. In administering the ordinances, the counties can decide whether to encourage or discourage wetland biomass development. If they decide to encourage this development, they must be careful to preserve the protection of their citizens, a crucial element of zoning ordinances.

2. As an owner and controller of a very large portion of the wetland base, the state of Minnesota must decide whether biomass production is an appropriate use of its lands. It must also decide whether this is the best use.

3. With world petroleum prices stable or falling, the time may not be right for heavy investment in a replacement fuel. However, research is best done in a non-crisis

environment, so now may be the best time to proceed. This investment could lower the cost of such fuels to make them competitive even today. If the nation or the state of Minnesota is truly interested in reducing dollar outflows to pay for liquid fuels, research and development dollars must be provided to make the alternative fuels available from biomass a reality. More publicly supported research and development is necessary before farmers and firms will be convinced to get started with biomass development.

4. The state and federal governments also can use more indirect methods to foster biomass development. These include the following. Any could be used to stimulate (or discourage) development.

   a. Tax breaks could be given on property and income taxes.

   b. Water appropriation and discharge permits could be made easy to obtain for such activity.

5. If peat extraction is eventually allowed and subsequent biomass development desired, policies must be developed to assure adequate reclamation following the peat mining.

6. The use of wetlands for biomass production will have some environmental impacts including impacts on flood control, water purity, and wildlife. Governments must decide what regulation to impose in order to reduce these impacts. This will require a balancing of public costs and benefits of biomass development.

APPENDIX A

Table 12. MINNESOTA'S WETLAND ACREAGE BY COUNTY (in thousands of acres)*

	Presettlement Wetlands			Current Wetland Base		
County	Wet Mineral Soils	Peat Soils	Total	Wet Mineral Soils	Peat Soils	Total
Aitkin	181	448	629	142	431	573
Anoka	27	59	86	17	44	61
Becker	36	50	86	9	38	47
Beltrami	403	624	1,027	354	612	966
Benton	55	8	63	36	5	41
Big Stone	115	0	115	2	0	2
Blue Earth	276	3	279	5	1	6
Brown	193	3	196	2	0	2
Carlton	35	99	134	30	95	125
Carver	13	11	24	1	3	4
Cass	184	223	407	169	203	372
Chippewa	195	1	196	1	+	1
Chisago	27	29	56	15	21	36
Clay	290	3	293	4	3	7
Clearwater	158	88	246	124	67	191
Cook	0	42	42	0	42	42
Cottonwood	40	0	40	0	0	0
Crow Wing	111	40	151	94	37	131
Dakota	13	15	28	+	4	4
Dodge	114	2	116	1	+	1
Douglas	23	11	34	5	7	12
Faribault	263	5	268	3	+	3
Fillmore	6	0	6	0	0	0
Freeborn	185	18	203	2	1	3

*All numbers have been rounded to the nearest 1,000 acres. Totals may appear incorrect due to rounding. Figures were produced from statewide data files which may be somewhat less accurate than county level data files.

+Less than 1,000 acres.

County	Presettlement Wetlands			Current Wetland Base		
	Wet Mineral Soils	Peat Soils	Total	Wet Mineral Soils	Peat Soils	Total
Goodhue	16	1	17	+	+	+
Grant	89	+	89	1	+	1
Hennepin	21	8	29	6	3	9
Hubbard	2	74	76	2	68	70
Houston	0	0	0	0	0	0
Isanti	0	60	60	0	48	48
Itasca	341	261	602	324	248	572
Jackson	146	1	147	2	0	2
Kanabec	29	40	69	25	35	60
Kandiyohi	183	29	212	11	10	21
Kittson	469	48	517	62	34	96
Koochiching	737	974	1,711	709	968	1,677
Lac Qui Parle	172	0	172	2	0	2
Lake	11	192	203	11	187	198
Lake of the Woods	290	430	720	213	425	638
Le Sueur	27	42	69	1	6	7
Lincoln	40	0	40	1	0	1
Lyon	107	0	107	1	0	1
McLeod	37	12	49	2	1	3
Mahnomen	48	8	56	6	7	13
Marshall	854	155	1,009	114	80	194
Martin	180	1	181	1	0	1
Meeker	94	26	120	16	10	26
Mille Lacs	23	70	93	19	65	84
Morrison	207	93	300	141	77	218
Mower	202	0	202	1	0	1
Murray	33	0	33	1	0	1
Nicollet	136	8	144	3	+	3
Nobles	137	0	137	+	0	+
Norman	250	2	252	6	1	7

County	Presettlement Wetlands: Wet Mineral Soils	Presettlement Wetlands: Peat Soils	Presettlement Wetlands: Total	Current Wetland Base: Wet Mineral Soils	Current Wetland Base: Peat Soils	Current Wetland Base: Total
Olmsted	9	+	9	+	0	+
Ottertail	61	92	153	17	67	84
Pennington	340	22	362	22	7	29
Pine	107	196	303	93	186	279
Pipestone	17	0	17	0	0	0
Polk	565	29	594	15	12	27
Pope	37	23	60	6	8	14
Ramsey	1	2	3	+	1	1
Red Lake	185	9	194	15	1	16
Redwood	171	0	171	1	0	1
Renville	238	1	239	1	0	1
Rice	27	11	38	2	3	5
Rock	3	0	3	0	0	0
Roseau	582	237	819	155	206	361
St. Louis	456	754	1,210	403	733	1,136
Scott	9	8	17	1	1	2
Sherburne	11	32	43	8	23	31
Sibley	286	4	290	6	+	6
Stearns	112	34	146	17	15	32
Steele	61	16	77	1	1	2
Stevens	61	0	61	1	0	1
Swift	233	3	236	9	1	10
Todd	183	28	211	93	19	112
Traverse	260	0	260	1	0	1
Wabasha	0	0	0	0	0	0
Wadena	15	78	93	10	58	68
Waseca	100	15	115	2	3	5
Washington	2	12	14	+	6	6
Watonwan	116	+	116	1	0	1
Wilkin	427	0	427	1	0	1

County	Presettlement Wetlands			Current Wetland Base		
	Wet Mineral Soils	Peat Soils	Total	Wet Mineral Soils	Peat Soils	Total
Winona	0	0	0	0	0	0
Wright	11	17	27	1	5	6
Yellow Medicine	133	0	133	1	0	1
STATE TOTAL*	12,643	5,940	18,583	3,580	5,243	8,823

*Slight discrepancies between state totals here and those resulting from our wetlands inventory are due both to rounding and to the constant updating of the state files by MLMIS. Data here were taken from the state files at least a year later than data used for the inventory.

APPENDIX B

OTHER LANDS FOR ENERGY CROPS

While the bulk of this study has considered Minnesota's wetlands to be the the lands where energy crops might best be grown, other types of lands should not be overlooked. The acreage of Minnesota's wetlands is considerable. Yet significant constraints exist, as we have seen, that may limit their development. Some wetlands are viewed as pristine wilderness; worthy of protection from all exploitation. Others are far removed from transportation networks and necessary service centers thus limiting their usefulness. And most wetlands would require a certain degree of water management in their development--a factor that could have a major impact on the local or regional hydrology.

Minnesota's marginal croplands may have a distinct advantage over the wetlands as a potential land resource for bioenergy. Many of these croplands are already cleared and are found in or near agricultural areas. Necessary service facilities and roads are often in place. If energy crops could be efficiently grown on marginal croplands, bioenergy could conceivably become an important aspect of the local farming economy.

DISTRIBUTION OF MINNESOTA'S CROPLAND

Agriculture is Minnesota's leading industry with nearly 45 percent of the state's gross receipts derived from agricultural products. In Minnesota more land is devoted to farming than to any other use. Thirty million acres of the state's 54.3 million acre total are in farms and the majority of these lands (65 percent) are used for growing crops.

Minnesota's major cropland regions are closely aligned to soil quality. The fertile prairie soils of southern Minnesota and the rich lacustrine deposits of the Red River Valley support the state's principal farming activity. In northeast Minnesota the shallow, infertile soils coupled with a harsh climate and an often rugged terrain significantly limit agricultural development.

Separating the state's cropland regions from the northeast is a loosely defined transitional zone where the soils are inherently marginal for crop production. This region is typified by a mixture of land uses including forests, open-pasture lands, and cultivated areas. The presence of cropland in this zone tends to fluctuate with the market prices for farm products. As prices rise, woodlots, pastures, and idle farmlands are improved for crop production. As prices fall, many of these same croplands are abandoned. As a result, this region has had a long history of changing cropland patterns. It is these marginal croplands that could become an important land resource for the production of bioenergy crops.

LOCATING THE MARGINAL CROPLANDS

We used the MLMIS, again, to prepare our inventory of Minnesota's marginal croplands. Marginal croplands were defined in this analysis by the following characteristics.

1. Naturally well drained soils. The Minnesota Soil Atlas provides a generalized statewide soil map. For this analysis all well drained soils regardless of texture, chemistry, or other features were chosen. Artifically drained soils were not considered.
2. Low or moderate productivity. The Minnesota Cropland Resources provides a five class index of potential productivity for Minnesota soils. Productivity classes 3 and 4 (moderate and low) were applied in this study. Classes 1 and 2 represent the state's most productive cropland while class 5 lands are generally unsuited for most cropping purposes.
3. Forested or open-pasture land uses. The 1969 Land Use Map displays nine classes of land uses. Only the forested and open-pasture uses were viewed as having potential for cropland expansion. Currently cultivated lands (1969) were not considered available for new cropping applications.

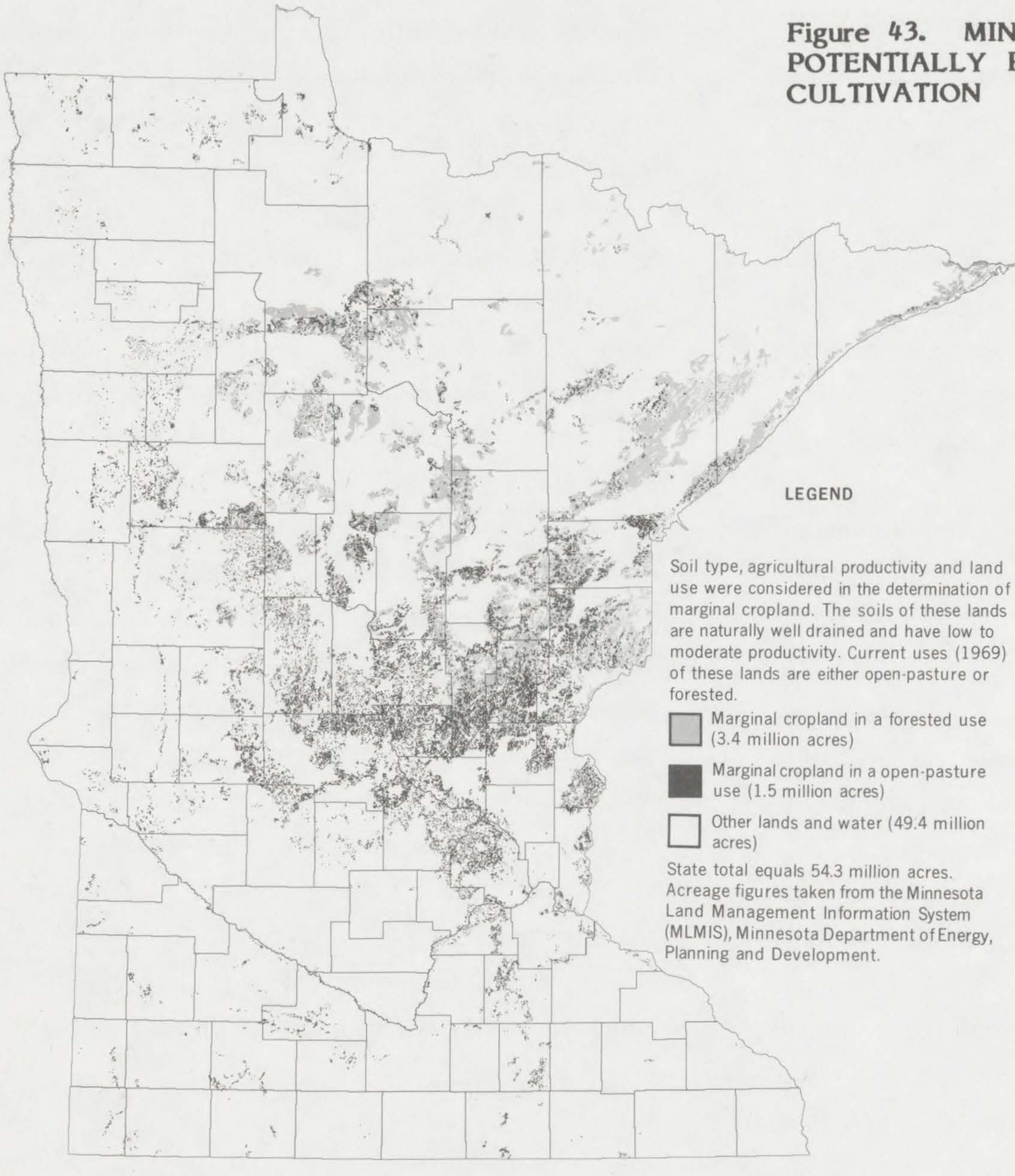
By applying these limitations to Minnesota's land base we were able to produce Figure 43, a base map of Minnesota's marginal croplands. Both forested and open-pasture lands are shown.

More than 3.4 million acres of marginal cropland are forested, representing 70 percent of the total. These lands, shown in gray, are aggregated into large contiguous blocks that are found primarily in north-central Minnesota. Other significant concentrations occur in the northeast, along Lake Superior, and to the south of the Iron Range in St. Louis County.

The marginal croplands in open-pasture are displayed in black. These lands (representing 1.5 million acres) are also clustered in central Minnesota but have a more scattered pattern than their forested counterparts. The fertile agricultural region of south-central Minnesota holds only small amounts of marginal croplands. Some of these can be seen in the southwest quadrant of the state and along the Mississippi and Minnesota river systems. Others constitute a loosely defined linear pattern that parallels the Red River Valley.

A detailed listing of the acreages for each Minnesota county is presented in Table 13.

Figure 43. MINNESOTA'S MARGINAL CROPLAND: POTENTIALLY PRODUCTIVE UPLANDS NOT UNDER CULTIVATION



LEGEND

Soil type, agricultural productivity and land use were considered in the determination of marginal cropland. The soils of these lands are naturally well drained and have low to moderate productivity. Current uses (1969) of these lands are either open-pasture or forested.

- Marginal cropland in a forested use (3.4 million acres)
- Marginal cropland in a open-pasture use (1.5 million acres)
- Other lands and water (49.4 million acres)

State total equals 54.3 million acres. Acreage figures taken from the Minnesota Land Management Information System (MLMIS), Minnesota Department of Energy, Planning and Development.

Table 13. MINNESOTA'S MARGINAL CROPLANDS BY COUNTY (in thousands of acres)

County	Forested	Open-Pasture	Total	County	Forested	Open-Pasture	Total
Aitkin	294	53	347	Itasca	185	16	201
Anoka	2	3	5	Jackson	+	2	2
Becker	51	55	106	Kanabec	122	81	203
Beltrami	201	38	239	Kandiyohi	9	17	26
Benton	26	73	99	Kittson	7	6	13
Big Stone	0	5	5	Koochiching	62	10	72
Blue Earth	+	+	+	Lac Qui Parle	0	3	3
Brown	3	9	12	Lake	172	5	177
Carlton	149	52	201	Lake of the Woods	19	8	27
Carver	4	5	9	Le Seuer	+	+	+
Cass	237	54	291	Lincoln	0	+	+
Chippewa	+	1	1	Lyon	+	3	3
Chisago	33	40	73	McLeod	+	+	+
Clay	1	13	14	Mahnomen	4	8	12
Clearwater	53	9	62	Marshall	3	3	6
Cook	105	2	107	Martin	0	+	+
Cottonwood	0	7	7	Meeker	1	7	8
Crow Wing	148	28	176	Mille Lacs	115	78	193
Dakota	4	6	10	Morrison	69	77	146
Dodge	0	+	+	Mower	+	+	+
Douglas	7	17	24	Murray	+	1	1
Faribault	0	0	0	Nicollet	+	+	+
Fillmore	0	0	0	Nobles	0	+	+
Freeborn	+	4	4	Norman	6	3	9
Goodhue	3	4	7	Olmsted	+	+	+
Grant	+	3	3	Ottertail	54	33	87
Hennepin	20	48	68	Pennington	2	+	2
Houston	0	0	0	Pine	284	103	387
Hubbard	135	12	147	Pipestone	0	2	2
Isanti	16	39	55	Polk	22	10	32

+ fewer than 1,000 acres

County	Forested	Open-Pasture	Total	County	Forested	Open-Pasture	Total
Pope	3	32	35	Swift	+	10	10
Ramsey	+	+	+	Todd	48	56	104
Red Lake	4	1	5	Traverse	0	+	+
Redwood	+	2	2	Wabasha	0	0	0
Renville	+	+	+	Wadena	36	14	50
Rice	5	15	20	Waseca	+	1	1
Rock	+	1	1	Washington	10	16	26
Roseau	14	11	25	Watonwan	+	2	2
St. Louis	578	45	623	Wilkin	0	+	+
Scott	11	12	23	Winona	0	+	+
Sherburne	19	28	47	Wright	28	33	61
Sibley	1	+	1	Yellow Medicine	0	2	2
Stearns	39	113	152				
Steele	+	9	9				
Stevens	+	5	5	TOTAL*	3,431	1,474	4,905

+ fewer than 1,000 acres

*Totals include acreage from counties with fewer than the 1,000 acre minimum required for separate reporting. The unallocated portions of these totals are (left to right) 7,000; 10,000; and 17,000 acres.

CONCLUSIONS

As defined here, more than 4.9 million acres of marginal croplands are found in Minnesota. Especially attractive are the marginal croplands that are situated in the north-central part of the state; a region where agriculture is an established industry. These lands have important advantages over wetlands as a prospective land base for producing energy crops. Many have been farmed in the past and could be improved for bioenergy applications with little difficulty. Because their soils are well drained, these lands do not present the water management problems which may hinder wetland development. Also, the techniques used to produce energy crops on uplands will more closely resemble traditional farming practices than the methods necessary to cultivate wetland crops such as cattails. For these reasons, existing farmers might be encouraged to include energy crops in their current operations.

If growing biomass became profitable, considerably more acreage than is shown in Figure 42 might become available. These would be lands of low to moderate productivity that are currently cultivated (as of 1969). On these lands, biomass would replace the presently grown agricultural crop. As a result, bioenergy could become a viable alternative for many of Minnesota's marginal croplands and play a major role in reducing the state's dependence on imported fuels.

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